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EVALUATION OF THE RECREATIONAL CATCH-AND-RELEASE FISHERY FOR
GOLDEN DORADO *SALMINUS BRASILIENSIS* IN SALTA, ARGENTINA:
IMPLICATIONS FOR CONSERVATION AND MANAGEMENT

A Thesis Presented

by

TYLER OSBORNE GAGNÉ

Submitted to the Graduate School of the University of Massachusetts in partial
fulfillment for the degree of

MASTER OF SCIENCE

February 2017

Department of Environmental Conservation

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DEDICATION

I dedicate this thesis to my family – Mom, Dad, and Heather – who have been my biggest source of support and encouragement on my path forward. I love you. I also dedicate this to people and the fish that made this project possible, you have made this achievable, I hope that this thesis is something small that gives back.

“Fish,” he said softly, aloud, “I’ll stay with you until I am dead.”

— Ernest Hemingway, *The Old Man and the Sea*

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ABSTRACT

EVALUATION OF THE RECREATIONAL CATCH-AND-RELEASE FISHERY FOR GOLDEN DORADO *SALMINUS BRASILIENSIS* IN SALTA, ARGENTINA: IMPLICATIONS FOR CONSERVATION AND MANAGEMENT

FEBRUARY 2017

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Golden dorado (*Salminus brasiliensis*, Cuvier, 1816) is increasing in popularity as a target for recreational anglers practicing catch-and-release (C&R) in northern Argentina and bordering countries. However, to date no research has looked at the potential social and ecological implications of growth in this recreational fishery. The first manuscript of this thesis assessed the consequences of C&R on golden dorado captured by anglers on the Juramento River in Salta, Argentina. This evaluation examined physical injury, physiological stress, reflex impairment, and short term post-release behavior to develop a clear set of evidence-based best practices for C&R. In addition, the Juramento River has limited resources for formal enforcement of angling practices. Consequently, the second manuscript of this thesis surveyed the social-ecological factors that predict anglers' willingness to play important sanctioning roles (i.e. self-policing) to improve best practices adoption. We obtained results that showed a combination of intrinsic values, demographics, and fishing practices predicted anglers' willingness to to sanction others. Taken together, the two body chapters of this thesis highlight the important role of addressing both ecological and social barriers to conservation in C&R fisheries.

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CHAPTER 1

GENERAL INTRODUCTION

Large River Ecology

Large rivers are ecologically and culturally iconic in the landscapes they are embedded in. Rivers encompass dynamic food webs and they function through a complex relationship between the aquatic and adjacent terrestrial habitat (Vannote et al. 1980). Because of this relationship, rivers can be greatly impacted by anthropogenic disturbance (Winemiller 1998; Hoeinghaus et al. 2009). In addition, multiple theories of river ecology have had to consider the connectivity and dynamics of rivers, from flood pulse theories that emphasize the importance of seasonal flow regimes (Junk, Bayley, & Sparks 1989) to river continuum theories that stress the gradient between different river orders and neighboring terrestrial conditions (Vannote et al. 1980). Across river systems, complexity has been the unifying factor that has defined theories around their ecology.

One key element of large river systems is the fish that inhabit them, and fish are known to be important linkages in both a trophic and spatial context (Winemiller 1998). Fish in rivers often function as conduits for energy and nutrients (Johnson, Richardson, & Naimo 1995). For instance, studies have demonstrated that fish such as salmon act as critical vectors for upstream nutrient transport in river systems (Naiman et al. 2002). Globally, neotropical rivers makeup a large proportion of rivers, yet limited work has been done examining the ecological role of fish in these watersheds. Findings suggest that in addition to the role of nutrient transport, neotropical river fish have displayed high trophic diversity, and piscivores have shown greater niche specificity than that of temperate river counterparts (Winemiller 1998). The diversity in feeding niches in

neotropical rivers results in fish playing substantial roles in aquatic food webs (Winemiller 1998). For example, migratory herbivorous fishes that are suited to eutrophic areas may supplement resident predators in areas that are oligotrophic, highlighting the reliance on connectivity and access to floodplain areas (Winemiller 1998). Overall, a key motivation in contributing to fish ecology research worldwide, and specifically in the neotropics, is that the roles and value of fish should not be underestimated.

Large Rivers As Ecosystem Service Providers

Freshwater river systems underpin the survival of the stakeholder communities locally tied to them (Agostinho et al. 1995). Since Mesopotamia, river resources use and extraction has generated sustenance, support, and economic resilience in areas surrounding rivers in the developed and developing world (Johnson et al. 1995). For example, rivers have served as sources of food, water, and power, and as vectors for transport and waste disposal (Welcomme et al. 1989). The ecological dynamics of rivers and the livelihoods they support lend themselves to complex environmental, economic, and social management concerns (Bower et al. 2014). As a broad example, drivers of conflict can be point and diffuse sources such as land use, pollution sources, and/or invasive species, or more indirect social controls such as cultural differences and resource competition (Arlinghaus et al. 2013). Almost universally, river conservation initiatives have had to balance the nuances of a system that requires an awareness of ecological research, stakeholder needs, ecosystem services, and social-economic drivers (Ives & Kendal 2014; Liu et al. 2007).

Recreational Fisheries

Defined broadly in Arlinghaus & Cooke (2009) “recreational fishing is fishing for aquatic animals that are not traded on domestic or export markets.” Under that definition, recreational fishing is an incredibly popular activity worldwide, across many systems, including freshwater, saltwater, tropical, temperate, and neotropical areas (Arlinghaus et al. 2007; Cooke & Cowx 2004). From fishing in urban centers for mixed freshwater species (Burger et al. 1999), to high end remote fly-in lodges targeting Muskie (Kerr 2007), to Mahseer fishing in South Asia (Dinesh et al. 2010) -- abundant examples exist of the immense popularity and reach of recreational fishing. Participation in recreational fishing is growing worldwide, where it may represent up to 12% of global annual fish catch (Ahmed et al. 2007; Cooke & Cowx 2004; Hickley 1998). Additionally, worldwide income generated through recreational fishing has been estimated to be in the billions of dollars annually (Arlinghaus et al. 2013). As a single example, an economic impact study of flats fishing in the Bahamas, valued the economic return to be \$141 million dollars to the Bahamian economy (Fedler 2010). In the majority of industrialized countries, recreational fishing has represented the major use of fish and aquatic wildlife in freshwater and many coastal areas (Cooke & Cowx 2004). As recreational fishing involvement grows, mounting influence both economically and ecologically will be tougher to ignore.

The dispersed nature of recreational fishing makes it difficult to monitor the condition of targeted populations spatially and temporally (Arlinghaus & Cooke 2009). Historically, recreational fishing was assumed to be a benign, low impact phenomenon that could be managed under a set of general assumptions of anglers and their impacts (

Cooke & Cowx 2006). This presumption is now under critique, as implications witnessed in popular recreational fisheries include declining catch rates, size distribution, and other indices of fishery health (Arlinghaus et al. 2010). The only assumption that can be made of recreational angling and anglers is that their defining factors are universally non-homogenous; it has been said “there is no average angler (Fisher 1997).” This statement has typically meant that methods, tools, motivations, locations, behaviors, class, perceptions, frequency, and the other factors that characterize an angler almost always vary between anglers and often in a single fishery. Angler heterogeneity is a continuing challenge for management bodies. The recognition of highly variable and omnipresent human factors in recreational fisheries has generated interest in developing more integrative management strategies that are adaptive to changing conditions (Hunt et al. 2013). Ideal strategies will integrate biological and social science to provide insights into the entire social-ecological system of recreational fisheries (Arlinghaus & Cooke 2009). Idyllically, interdisciplinary approaches will help to identify both biological and human constraints for conservation.

While recreational fishing is primarily considered a leisure activity, historically, in many fisheries a portion of fish catch has been kept for domestic consumption. Though, a growing regulatory protocol is to catch-and-release fish (C&R) (Policansky 2002). C&R techniques are often employed by managers in fisheries as a conservation tool (Policansky 2002). Intuitively, managers have believed catch rates and size ranges increase with C&R when fish rejoin the local population and continue to grow. Yet, a number of studies have highlighted while C&R has the potential to be a useful tool to mitigate harvest impacts, there may still be substantial post-release mortality or sub-lethal

impacts (Cooke et al. 2013). For many species and locales, the extent to which fish released end up dead or suffer from sub-lethal impacts on growth, reproduction, and or general fitness consequences is unknown. Central to maximizing C&R conservation efficacy is evaluating stressors and stress response specific to species and regions (Cooke & Suski 2005). Subsequently, evidence from stress evaluation research can outline best practices for conservation. Research preferably should simultaneously also explore effective methods for adoption and dissemination of evidence backed best practices. Without pairing ecological assessment with social science research, it will be nearly impossible to fully evaluate the sustainability of C&R fisheries. Preferably, the future decisions of resource managers will be based on scientifically valid evidence, rather than the historical precedent of intuition.

In less developed nations the importance of recreational fishing is growing rapidly. Fish that have been advertised as focal species for recreational fishery development include but are not limited to Mahseer of South Asia (Dinesh et al. 2010), Taimen of Central Asia (Jensen et al. 2009), Araipima of South America, Giant Trevally of Oceania, and Golden Dorado of South America. Recreational fishing in less developed countries represents alternative income generation where fisheries may be under significant pressure of overharvest, and where tourism poses an alternative to resource extraction. Overall, recreational fishing continues to represent a growing sector worldwide that will require vigilante and progressive management.

Catch-And-Release Science and Stress Response

There is a growing body of research on a number of fish species that has

examined the relationships among elements of the angling event and physical injury, physiological stress, and post-release mortality (Suski et al. 2007; Danylchuk et al. 2007; Skomal 2007; Cooke et al. 2012; Cooke et al. 2013). Impacts of angling on fish can be associated with factors such as fight time (Brownscombe et al. 2014), water temperature (Havn et al. 2015), hook damage (Meka 2004), and air exposure (Suski et al. 2007), and be measured by examining blood physiology, post-release movement, reflex impairment, and mortality (*reviewed in* Cooke et al. 2013). Often fisheries managers rarely have species-specific data and best practices may rely on anecdote or conjecture. An explicit understanding of the response to stressors needs to be taken in to consideration when developing C&R management guidance (Arlinghaus et al. 2007). Studies that have looked at species-specific response in the context of authentic rather than simulated angling events is limited (Robert Arlinghaus et al. 2007).

Stress is a response triggered when an organism deviates from a physiological stable state (Barton 2002). Potential stressors in C&R fishing can include muscle stress, air exposure, and injury (Ferguson & Tufts 1992; Meka 2004). When fish are stressed, a number of physiological change occurs, physiological response occurs to meet the demands of intensive exercise and additional stressors (Cooke et al. 2013). Measureable response in blood can originate from muscle use of energy stores, varied muscle type utilization, reduced gas exchange, and fluctuation of hormone and ion levels (Wood 1991). To parse out the origins of various physiological stress responses, it is necessary to understand the mechanisms that drive different physiological measures. For example, glucose is mobilized in the bloodstream to meet the energetic demands, and increased levels of lactate in white muscle is a product of anaerobic muscle use (Wood 1991).

Additionally, gas exchange across the gill lamellae may be impaired due to air exposure that impairs lamellae efficacy, and a pH decrease can be measured in the blood stream when plasma acidification occurs (Milligan & Wood 1986). In the framework of management, an understanding of the mechanisms that drive physiological response can be used to guide the development of sustainable angling practices in a species specific and environmentally relevant manner (Cooke et al. 2013).

In addition to physiological response, the tertiary effects of physiological response can be evaluated through assessing reflex impairment (Davis 2010). Studies have demonstrated that angling events induce physiological stress that can result in reflex impairment (Cooke et al. 2013; Davis 2010; Raby et al. 2012). Components of whole-animal condition, performance, and vitality can be measured using a suite of reflex tests to assess general condition and potentially predict mortality. Often the collective test is referred to as RAMP or reflex action mortality predictor test (Raby et al. 2012). Reflex impairment has been shown to provide a reliable index to assess sub-mortality effects in fish (Raby et al. 2012).

In addition to physiological and reflex response, post-release movement and behavior can be a tertiary stress response that may be indicative of longer-term effects of an angling event (Makinen et al. 2000). Delayed effects can include affected spawning ability or susceptibility to predation (Makinen et al. 2000; Danylchuk et al. 2007; Gravel & Cooke 2008). For fish in fast flowing rivers, a measure of delayed impact is post-release fallback (downstream movement) that can occur as a result of cumulative physical and physiological impacts associated with capture, handling, and release (Havn et al. 2015; Makinen et al. 2000). Departures from traditional migratory patterns immediately

after release have been observed for the catch-and-release of Atlantic salmon (Makinen et al. 2000). While catch-and-release fishing offers the potential of low mortality, downstream movement may be detrimental for potadromous species such as golden dorado, which travel upstream to spawn (Hahn et al. 2011).

Recreational Fisheries as Social-Ecological Systems

Studies that examine social-economics and resource conflicts that may arise from the growth of recreational fisheries is sporadic (Hunt et al. 2013). Though recreational fisheries are acknowledged as coupled coupled human-resource systems, motivations for applied research rarely incorporate this structure in research objectives (Hunt et al. 2013; Nadasdy 2005). For example, perceptions and attitudes of fishery threats can be in conflict due to a number of factors, including: conflict resolution methods, cultural values, and conservation challenges (Bower et al. 2014). In addition, the varying incentives to adopt C&R should be acknowledged, potential examples include: increased foreign attention and publicity, increasing ease of access, or regional conservation concern (Jensen et al. 2009; Wood et al. 2013). Almost universally, effective C&R management depends on the bridging the gap between the ecological development and research that investigates stakeholder adoption of sustainable management practices (Arlinghaus & Cooke 2009; Danylchuk et al. 2011).

In many transitioning fisheries regulation and management is impeded by poor funding and limited resources. As such, alternative avenues of management show promise of resiliency and achieving conservation goals (Ostrom et al. 1992). Interpersonal sanctioning may be a resource to encourage resilient C&R fishery management. Sanctioning has been investigated in other fields (recycling; Czopp 2013,

littering; Nolan 2013) with encouraging results of fostered pro-environmental behaviors in response to transgressor intervention. No research to date has explored the viability and predictors of sanctioning intentions in the context of recreational fisheries conservation. Interpersonal communication is a powerful component contributing to recreational fisher experience and values (Fenichel et al. 2013). Based on sanctioning efficacy in other conservation-concerned arenas, it appears beneficial to consider how the adoption of sustainable angling practices are perpetuated through angler groups. Identifying how values and demographics may motivate and influence sanctioning intentions could prove to be a useful for understanding the human-resource systems tied to recreational fishing.

Species and Regional Context: Golden Dorado and the Juramento River

Golden dorado (*Salminus brasiliensis*, Cuvier, 1816), sometimes known in different regions simply as dorado or dourado are a potadromous species of the order *Characiformes*, family *Bryconidae*. Golden dorado are native to neotropical South America, including the countries of Brazil, Bolivia, Uruguay, Paraguay, and Argentina. Golden dorado is a popular game fish and food fish, some stocking and aquaculture has been conducted in South America in to ponds and rivers for harvest and angling (Rodríguez-Olarte & Taphorn, 2006). Golden dorado are a fusiform shaped fish, with a moderately compressed body, a terminal mouth with a single row of sharp teeth, a forked caudal fin, and soft rayed pectoral, dorsal, pelvic, and anal fins. Golden dorado exhibit a striking golden-yellow body coloring, with tones of red ventrally, and tones of green dorsally, also a single dark black horizontal stripe is often present on the caudal fin. Adult

dorado are typically top piscivores in the river landscapes they inhabit, usually feeding in moving water in late evening periods (Hahn et al. 2011). Preliminary research have found diets composed of various shad, silverside species: (*Prochilodus lineatus*, *Leporinum obstusidens*), pejerrey (*Odonthethes bonariensis*), eel, armored catfish (*Heptapterus mustelinus*, *Hypostomus spp.*; Aguilera et al. 2013). Golden dorado have been reported in lengths up to 1 m, and weights up to 30 kg (Aguilera et al. 2013). Golden dorado are egg laying Characins that have been reported to make long 400 km+ freshwater river migrations triggered by flooding cycles to spawn in nutrient rich flooded marshes (Hahn et al. 2011). Beyond the large coarse-scale movements observed in the single telemetry study conducted by Hahn et al. (2011), only anecdotal evidence exists to suggest that the potadromous migrations are universal across different rivers.

The Juramento River is a large floodplain river and an incredibly valuable resource in the Salta region. A diversity of stakeholders utilize the river and native fish for a number of uses; from agricultural water supply, to small scale subsistence fish harvest, to C&R-only recreational fishing. A unified discontent across stakeholder groups is the limited capacity of formal regulatory enforcement actors, violations include illicit agricultural water use and illegal fish harvest (Personal communication, recreational fishing guide, interview, 2015). Recreational angling has a strong stakeholder presence on the Juramento River and it has been communicated that formal enforcement capacity is limited and often nonexistent (Personal communication, recreational fishing guide, interview, 2015). The Juramento River encompasses a watershed with a persistent need to identify management methodologies that improve golden dorado and river conservation outcomes in the region. The challenges that Juramento River faces are analogous to

challenges that many regions with emerging C&R fisheries face, successes and failures here will ideally act as transferrable lessons in C&R fishery management.

Purpose of Thesis

The overarching objective of my thesis research was to examine the response of golden dorado to C&R fishing, as well as understand the social-ecological context by which best practices for C&R could be communicated within the local angling community. The first part of my thesis examined quantified the physical injury, physiological stress response and post-release movements of golden dorado caught and release by recreational anglers fishing in the Juramento River (Chapter 2). Response measures include: blood glucose, blood pH, blood lactate, reflex impairment, and release behavior. Through an examination of the relationship of the stress response and elements of the angling event, this segment of my thesis can provide a solid foundation for best practices guidelines for golden dorado.

The second component of my thesis surveyed recreational anglers using the watershed and targeting golden dorado to examine the pathways to adoption for the species specific best practices (Chapter 3). For this study, I conducted online and in-person, semi-structured surveys with dorado anglers. The survey quantified the intentions of anglers to sanction in response to transgressions detrimental to the survival of golden dorado following C&R. Overall, the broad motivation of the survey was to support and highlight the role that anglers play in resource management and the perpetuation of conservation minded angling practices.

The last chapter of the thesis is a synthesis of the results and interpretation of the C&R assessment (Chapter 2) and social science survey (Chapter 3). I use this chapter to integrate the outcomes of the two studies and highlight how this work can strengthen the conservation and management of golden dorado recreational fishery on the Juramento River. My work also can be used as an integrative model that can be used in the development of a decision-making and research framework for evaluating remote and sensitive C&R fisheries in other social-ecological systems.

CHAPTER 2

**EVALUATING THE CONSEQUENCES OF CATCH-AND-RELEASE
RECREATIONAL ANGLING ON GOLDEN DORADO (*SALMINUS
BRASILIENSIS*) IN SALTA, ARGENTINA**

Abstract

Golden dorado (*Salminus brasiliensis*) is increasing in popularity as a target of recreational anglers practicing catch-and-release (C&R) in northern Argentina and bordering countries, however science-based best practices have yet to be developed for this iconic freshwater gamefish. We assessed the consequences of C&R on golden dorado captured by anglers on the Juramento River, in Salta, Argentina. Physical injury, physiological stress responses (blood glucose, lactate, pH), reflex impairment, and movement response post-release were compared among handling treatments for golden dorado. The 0 min and 2 min air exposure groups had significantly higher blood glucose and blood lactate concentrations relative to fish in the baseline group, while blood pH indicated evidence of acidosis in the 2 min air exposure treatment relative to baseline values. Golden dorado in the 2 min air exposure group also had significantly greater reflex impairment compared to fish without air exposure. An additional 24 golden dorado were affixed with radio tags to examine short-term (20 min) post-release behavior with air-exposure treatments of 0 min (n=11) and 2 min (n=9), as well as fish that were transported downstream in submerged recovery bags (n=4). Subsequent relocations of tagged golden dorado were conducted every 1-2 days up to 8 weeks after capture. Upon immediate release, fish often exhibited fallback (-43 ± 49 m, n=20), although post-release movement was not significantly different among treatment groups. Fallback distance was

correlated with total reflex impairment scores. The translocated fish released downstream exhibited greater upstream movement immediately following release, with three fish returning to the location of capture within 4-12 days. No immediate mortality was observed for golden dorado in the physiology assessment, and limited evidence of short-term mortality was present for tracked fish (22 of 24 tagged fish movement detected >2 days post-tagging, $\leq 8\%$ mortality). Our results indicate that minimizing air exposure should be advocated as part of guidelines for C&R for golden dorado. Our study also revealed that impairment of the equilibrium reflex is useful for anglers as an indicator for golden dorado vitality and potential need for monitoring recovery prior to release.

Introduction

Catch-and-release (C&R), whether to comply with regulations or because of conservation ethic, is a common strategy for the conservation and management of recreational fish stocks (Arlinghaus et al. 2007; Danylchuk & Cooke 2011)). The prevailing assumption of this strategy is that fish survive with negligible injuries or sub-lethal alterations in behavior or physiology (Cooke & Schramm 2007; Cooke et al. 2012). Nevertheless, studies on a number of recreationally targeted species have shown wide-ranging responses to C&R angling including physical injury (Cooke & Suski 2004; Skomal 2007), prolonged physiological recovery periods (Suski et al. 2007; Cooke et al. 2013), reflex impairment (Davis 2010; Brownscombe et al. 2013; Brownscombe et al. 2015) , post-release predation (Cooke & Philipp. 2004; Campbell et al. 2010), delayed mortality (Diamond & Campbell 2009), alterations in behavior (Rapp et al. 2012), and reduced spawning success (Richard et al. 2013). Individual recovery from C&R angling is context specific (Raby et al. 2015) and can vary according to species (Cooke & Suski 2005), angling gear (Dotson 1982), handling practices (Rapp et al. 2012), hook location (Meka 2004), water temperature (Gale et al. 2013), duration of air exposure (Ferguson & Tufts 1992; Suski et al. 2007), life history stage (Brobbe et al. 1996), body size (Lukacovic & Uphoff 2002), and depth of capture (Jarvis & Lowe 2008).

While C&R is often promoted as a conservation measure, it is frequently employed without an understanding of how elements of an angling event actually influence the fate of fish once released (Arlinghaus et al. 2007; Cooke & Schramm 2007). Although a list of best practices can be applied across species and has shown promise at mitigating sub-lethal impacts and mortality (Cooke & Suski 2005), such general

guidelines can be vague or provide conflicting advice on best practices for capture and release in particular environments and certain species (Pelletier et al. 2007). Species-specific variation in response to C&R should be considered when developing guidelines for the use of this conservation tool (Cooke & Suski 2005). Context specific management is pertinent in recreational fisheries in emerging economies where there is limited capacity for management, increasing pressures for resource development, and limited basic knowledge of recreationally targeted and often imperiled species (Bower et al. 2014; Cooke et al. In Press).

Recreational angling is growing in popularity in emerging economies and remote locations around the world (Bower et al. 2014; Barnett et al. In Press), with C&R fishing often being presented as a non-destructive way to protect fish stocks while providing additional economic opportunities (Wood et al. 2013; Barnett et al. In Press; Cooke et al. In Press). Golden dorado (*Salminus brasiliensis*) in the Juramento River of Salta, Argentina, is an example of a growing remote C&R fishery in South America. The Juramento River has historically been a hook and line subsistence harvest fishery for bagre *Heptapterus mustelinus*, sábalo *Prochilodus lineatus*, pejerreyes *Odonthehes bonariensis*, palometa *Serrasalmus sp.*, and golden dorado (*Salminus brasiliensis*). Golden dorado in the Juramento River are piscivorous, egg laying, potadromous fish of the Characidae family (Aguilera et al. 2013). Golden dorado are also found in rivers of Bolivia, Brazil, Paraguay, and Uruguay (Hahn et al. 2011). Recently golden dorado in the Juramento River were placed under a C&R-only regulation by the provincial Environmental Ministry. To date, however, no study has been conducted to evaluate the consequences of C&R on golden dorado.

The purpose of our study was to evaluate the impacts of C&R on golden dorado in the emerging recreational fishery on the Juramento River. Specifically, we quantified physical injuries, physiological stress responses, reflex impairment, immediate and short-term mortality, and short-term movement patterns of golden dorado following capture and release. We predicted that golden dorado that experienced greater fight times and duration of air exposure would show elevated physiological stress indices, reflex impairment, and greater fallback distances following release.

Materials and Methods

Study Site and Capture Methods

Golden dorado were sampled from May 2, 2015 to June 29, 2015 on the Juramento River in the northern Argentinian province of Salta (Fig. 2.1). The river is fished on guided trips with anglers from the region. The river is also regularly fished without guides by local anglers. C&R fishing for golden dorado is mandated in the region by the local enforcement agency, although anecdotal reports of harvest of golden dorado still continues (Alejandro Haro, Juramento Fly Fishing, pers. comm. 2015). The climate of the Neotropical Chaco region in Salta is characterized by distinct seasons, a cooler dry season from May through August, and a warmer wet season from September through March. The Juramento River is the upper reach of the Salado River, which drains into the Paraná River basin. The Juramento River is turbid with high sediment load and bank deposition from adjacent intensive agricultural land use runoff, and features substantial and often unregulated irrigation diversion canals. The reach of the river included in our study is regulated by a 5 Mw hydropower earthen dam without fish passage. The dam

marked the upstream limit of our study site and the downstream study limit was the small settlement of El Quebrachal (pop: 4500), covering a total distance was approximately 100 km (Fig. 2.1).

Angling was conducted from rafts that drifted with the current. Fish were caught by recreational anglers via fly fishing (6-8 weight rods, 9-14 kg leaders with 14 kg wire tippet, barbed size 3-4 flies on single J-hooks). When hooked, anglers fought and landed the golden dorado using practices common to the fishery. Fish were hooked and fought while the raft was rowed to a nearby shallow bank, after which the angler would step out of the raft and land the fish with the assistance of an additional angler or fishing guide. All research was conducted in accordance with the policies of the American Association for Laboratory Animal Science (IACUC protocol 2013-0031, University of Massachusetts Amherst, Amherst, MA, USA).

Quantification of the Angling Event

For each angling event, we quantified fight duration (sec), anatomical hooking location, difficulty of hook removal, presence of bleeding or tissue damage at the hook insertion point, water temperature, and fish size (fork length, mm). The duration of the fight was calculated to be the time from a hook set to the time the angler had secured and landed the fish in water. Hook removal difficulty was a 1-5 interval scoring system, 1 indicated that the hook was removed with no effort (i.e., hook fell out as soon as line tension was released) and 5 requiring considerable force with the use of pliers, typical of a deeply set, or entangled hook.

Physiological Assessment

Fish were divided into one of three treatment groups: baseline ($n=14$, 492 ± 140 mm), no air exposure treatments ($n=12$, 552 ± 90 mm), or 2 min air exposure treatments ($n=10$, 560 ± 86 mm). The exposure time of 2 min was chosen since it emulated the average hook removal and admiration period observed in the fishery (Alejandro Haro, Juramento Fly Fishing pers. comm. 2015). Air exposure treatments were conducted by elevating fish held in recovery bags in order to simulate air exposure, while also minimizing variation in handling across experimental units. Immediately post-capture, fish in the baseline group had approximately ~ 1.5 mL of blood drawn via a caudal venipuncture using a 21 g needle (BD, Franklin Lakes, NJ, 21 g, 38 mm, Ref: 305167) and 3 mL Vacutainer (BD, Franklin Lakes, NJ, 4.5 mL, 83 USP lithium heparin, Ref: 367962). Fish were held in the water and supported ventral side up in recovery bags (Dynamic Aqua Ltd., Vancouver, BC, 125 cm x 30 cm Hypalon with 0.5 cm mesh on both ends; see Donaldson et al., 2013 for description) for the blood sampling procedure. Fish in 0 min and 2 min treatment groups were placed into a recovery bag for 1 h prior to phlebotomy. The intention of the recovery bag use was two-fold; first, through the use of pre- and post-bag reflex evaluation, we were able to evaluate the potential for recovery bags to act as resuscitation and monitoring tools. Secondly, blood physiology stress for the indices recorded commonly peak approximately 1 h post-angling in most teleost fish (reviewed by Cooke et al. 2013). While some additional confinement stress was likely, the use of the recovery bag was the best field-based approach to retain and evaluate delayed stress response in angled fish. Fish held in the recovery bag period remained calm, often swimming slowly in to the direction of the current. Blood was immediately

analyzed at the time of bleed using point-of-care field physiology meters (Cooke et al., 2008; Stoot et al., 2014) for blood-plasma lactate (mg/dL, Lactate Plus, Nova Biomedical Corporation, Waltham, MA, USA), glucose (mg/dL, Accu-Check Compact Plus, Roche Diagnostics, Basel, Switzerland) and pH (HI-99161 w/automated temperature compensation, Hanna Instruments, Woonsocket, Rhode Island, USA).

Reflex Impairment

Golden dorado were assessed for five reflex action mortality predictors (RAMP; Davis, 2010): tail grab, equilibrium, body flex, head complex, and vestibular-ocular reflex (VOR). These predictors were chosen because they were effective indicators of fish condition in other C&R studies (Brownscombe et al. 2013; 2014; Lennox et al. 2015). Reflex assessments (RAMP 1, Table 2.1) were conducted immediately post angling and air exposure treatment for all assessments (blood physiology, and short-term movement response). To evaluate the potential effectiveness of recovery bag and track recovery time courses, reflexes for each fish were also assessed a second time (RAMP 2, Table 2.1) after the 1 h holding period in the recovery bag. To test for tail grab reflex the fish's tail was hand held while in the water; the fish trying to escape the handler indicated a positive response. Rotating the fish ventral side up was used to assess equilibrium status; the fish righting itself within 3 s indicated a positive response. Lifting the fish into the air by center of the body assessed body flex; an active flex of the body indicated a positive response. Observing the fish's operculum tested head complex; consistent, rhythmic opercula movements indicated a positive response. Lastly, VOR was assessed by rolling the fish side to side in the water, with a positive response dictated by the fish's

eye moving in response to remain level with the horizon. In the field, a passing response was scored as zero and a failed reflex response scored 1, reflex tests took approximately 20 s to complete. During analysis, the 0 – 5 cumulative scores were converted to 0 – 1 proportional values of impairment. These tests were used with the other assessments because they have shown promise in a number of studies to be rather effective measures of impairment in a range of teleost fish (Davis 2010; Raby et al. 2012; Brownscombe et al. 2013, 2014).

Short term Post-Release Behavior

Additional golden dorado were captured and released to measure post-release movements, with these fish either not exposed to air ($n=11$, 605 ± 92 mm) or exposed to air for 2 min ($n=9$, 601 ± 77 mm). Prior to release the five reflexes were assessed and then a radio tag (2 g in air, 13 x 6 x 18 mm, 110 mm antenna, ~150 day battery life, 1.1 – 2.0 sec pulse interval; Series F1900, Advanced Telemetry Systems, Isanti, MN, USA) was attached immediately ventral to the posterior end of the dorsal fin (following methods described by Cooke et al. 2003). Tagging involved supporting the fish in the water with the head upstream, dorsal side up, with two stainless 16 g surgical needles inserted into the dorsal musculature below the dorsal fin rays, to which 20 g coated stainless wire attached to the tag was inserted and the surgical needles removed. To protect the tissue, plastic backing plates were used prior to crimping the coated wire ends. All equipment was cleaned with an antiseptic solution of isopropyl alcohol. Mass of the transmitters were <2% of fish body mass, based on weight estimations from earlier length-weight relationships collected on the river (Aguilera et al. 2013). No anesthesia

was used owing to the limited-invasive nature of the tagging, the ease of fish handling and control by the research team, and in order to minimize the confounding effects of the tagging process on post-release behavior associated with angling. The average tagging time from tag attachment to release was $5 \text{ min } 9 \text{ s} \pm 2 \text{ min } 49 \text{ s}$.

Fish were manually tracked using a radio telemetry receiver (Lotek Biotracker, Lotek Wireless, Ontario, Canada) with a 3-element yagi antenna. Range of detection and precision for relocating fixed tags suspended in 30 cm, 60 cm 120 cm of water in *in situ* was approximately a 5 m radius within a range of 25 m (field calibration, June 2015). The average thalweg depth between El Tunal and Gaona was $1.15 \pm 0.4 \text{ m}$ with no significant differences between upstream and downstream reaches (randomized depth survey, 21-23 June 2015). Fish locations were obtained using successive gain reductions (zero-point tracking: (Gravel & Cooke 2008). Fish tracking took place immediately after release for 20 min. The period of time to first stationary location was recorded, and the position at 20 min was recorded. Subsequent point relocations of tagged fish were conducted for the entire study period to obtain daily rates of movement. River line positions were recorded using a handheld GPS instrument (Garmin 65csx, Lenexa, KS, USA) set to Universal Transverse Mercator projection. In addition, site-specific variables such as surface water speed (m/s) and water temperature (C°) were measured and calculated using a float timed traversing downstream a fixed distance (3 m) and handheld digital thermometer respectively (Taylor Precision Digital Thermometer, #9847, Taylor USA, Oak Brook, IL, USA).

Translocation Tagging Events

Given that the recreational fishery in the Juramento River operates out of rafts and anglers continue to fish as the raft floats downstream (i.e. fishing location is rarely static) fish held in recovery bags would be translocated prior to release. To investigate the impact of this practice on golden dorado recovery and movement, four fish (665 ± 72 mm) were angled, handled, placed in to a recovery bag and drifted downstream behind the raft for 1 h. Fish were then tagged, released and tracked. Short-term movement of these fish was monitored for 20 min in congruence with the methods used to track other tagged fish, and subsequently all tagged fish in our study (0 min air exposure, 2 min air exposure, translocated) were monitored daily for point relocations.

Data Analysis

Golden dorado fork lengths and fight times were compared among treatments with one-way ANOVAs. To distinguish factors that were best predictors of reflex response, physiological, and movement response, generalized linear models were developed for blood glucose, lactate, pH, reflex impairment, and linear river movement from full candidate models. Blood lactate, glucose, pH, and reflex impairment models were generated containing: hook removal difficulty, fight time, water temperature, and air exposure treatment. Full candidate models were selected for parsimony using second-order Akaike Information Criterion (AICc) and the R package *glmulti* (*glmulti* package in R, Calcagno 2013). After model selection was performed on full models, we ensured assumptions were met by examining plots of standardized residuals verses theoretical quartiles (q-q plots), plots of residual verses fitted values, variance inflation, checking the variance of residuals, and examined outliers with Cook's distance calculation. Data are

presented as mean \pm SD unless otherwise noted, and level of significance for statistical tests was $p \leq 0.05$. All analyses were conducted using RStudio (v. 0.97.314, R Core Team, Boston, MA, USA).

For linear movement values, fish locations were plotted along an up to date river line layer (collected June 2015) and plotted in a Geographic Information System (GIS). Individual fish location points were snapped to the nearest point on the river line, and individual distances from release site were calculated using network analyst tools in ArcMap (ESRI 2014. ArcGIS Desktop: Release 10. Redlands, CA: Environmental Systems Research Institute). Model selection was run using the R package *glmulti* (*glmulti* package in R, Calcagno 2013) for the full candidate model of linear movement distance relative to release site (fallback/upstream distance) including the predictors of reflex impairment total score, fight time, air exposure treatment, and hook removal difficulty. There was no significant difference of water flow between the two air exposure treatments ($F_{1,10} = 1.91$ $p = 0.197$), thus it was eliminated from the model development and selection.

Results

Across all treatments, 60 fish (561 ± 108 mm FL) were landed out of 184 hook strikes during 869 individual fishing hours. Discharge at the upstream dam during the study period averaged 33.3 ± 2.6 cubic meters per second with water temperatures averaging 19.1 ± 1.7 °C with a range of 16.3 – 22.7 °C.

Physical Injury

For all fish captured ($n=60$), mean hook removal difficulty was 2.6 ± 1.2 , with 2% of hooking events resulting in bleeding. Hooking locations were predominantly in the corner of the jaw (75%). Hooking in the tongue (12%) and front lip (8%) were infrequent and 5% were classed as deep-hooked (i.e. either in the esophagus or gill arch area). Fight time ranged from 30 to 554 s (170 ± 106 s), and fight times were positively correlated with fish size ($r = 0.71$, $p < 0.05$).

Physiological Response and Reflex Impairment

Fish used in the physiological component of the study were of similar size (i.e., fork length) in the three treatments (baseline, 0 min air, 2 min air; $F_{2,33} = 1.41$ $p = 0.26$). Mean physiological responses for baseline fish were: blood glucose, 55.3 ± 12.3 mg/dL, blood lactate, 125.1 ± 68.8 mg/dL and blood pH, 7.5 ± 0.1 . After 1 h of holding, mean glucose was 125.5 ± 23.7 mg/dL, mean lactate was 173.0 ± 39.6 mg/dL, and mean pH was 7.37 ± 0.16 . While not significant, mean blood lactate was higher on average for air exposed fish than 0 min air exposed fish (Fig. 2.2 and Table 2.1). Mean blood pH was significantly different between baseline and air exposed treatment groups (Fig. 2.2; $p = 0.05$, post-hoc Tukey-Kramer HSD), with pH being lowest for the 2 min air exposure treatment.

The mean reflex impairment score was greater for the 2 min air exposure treatment (Table 2.3) (mean = 0.38) relative to the 0 min air exposure treatment (mean = 0.23 ($t = -1.5$, $df = 18.71$, $p = 0.16$, Welch two sample t-test). Body flex, tail grab, and equilibrium were the most prevalent reflexes impaired independent of treatment, with a higher proportion of impairment within air exposure groups (Fig. 2.3). Although not

significant ($p=0.131$, post-hoc Tukey-Kramer HSD), golden dorado exposed to air tended to have increased incidences of equilibrium loss (Fig. 2.3 and Table 2.1). Though as the physiological and reflex impairment results are not equivocal in their findings, the efficacy of these diagnostic tools used need to be critiqued further in future studies. Lastly, no fish experienced immediate mortality when landed or at time of release.

Short-Term Behavior

Twenty fish were tagged to assess short-term behavioral responses to C&R, 11 with 0 min air exposure, and 9 with 2 min of air exposure. Fish in both treatments were of similar size (i.e., fork length; $F_{1,18} = 0.73$ $p = 0.40$). There was no significant difference in the fallback distance between fish in the 0 min air exposure (-40.1 ± 58.8 m, *negative distance values represent downstream movement*) and 2 min air exposure groups (-47.4 ± 37.8 m; $t=0.3$, $df = 17.1$, $p=0.7$, Welch two sample t-test; Fig. 2.4). Independent of treatment, 58% of fish reached a stationary position (no movement for >2 min) within 5 minutes following release, and 95% of fish reached a stationary position within 10 min.

Although there was no significant difference in mean fallback distances between treatments, total reflex impairment score was the best predictor based on AICc (Fig. 2.5 and Table 2.2). A total of 22 of 24 total radio tagged golden dorado were relocated for the entirety of the tracking period (42 days), and their movements suggest that low mortality occurred for these fish. If we presume that the two fish that were not relocated died, post-release mortality for this study was 8%. For relocations, 62% of tagged fish were found along the outer bank of a river bend, 2% were located along the inside bank, and 36% were located along a straight run bank.

Translocation and Prolonged Tracking

Mean distance of translocation (~ 45 min - 1 h downstream) was 2800 ± 909 m. Recovery bag retention and translocation resulted in a mean fallback of -9 ± 90 m within the first 20 min relative to the immediate capture and release mean fallback of -43 ± 49 m. Rates of movement (m/day) were significantly greater for translocated golden dorado (189 ± 275 m/day) when compared to golden dorado immediately released following tagging (43 ± 78 m/day; Fig. 2.6; $t=2.22$, $df=18$, $p=0.04$, Welch t-test). Three of four translocated fish returned upstream within 750 m of the capture site within 4-12 days of release, while the one remaining fish remained >2 km downstream from the capture site.

Discussion

C&R fishing for golden dorado represents an increasingly popular fishery in Northern Argentina, and as pressure and interest grows, as does the potential cumulative impact of increased catch-and-release fishing pressure (Cooke & Suski 2005). Better understanding species-specific best practices and assessment methodology offers the chance to help contribute to the sustainability of this industry (Granek et al. 2008; Barnett et al. In Press). As demonstrated by our study, C&R angling can induce stress and impair reflexes of golden dorado, however, hooking injury beyond simple insertion were low. Additionally, 22 of 24 tag relocations suggested that short-term post-release mortality was relatively low (8% maximum). Our study acts as the foundation for best practices for the C&R of golden dorado in Northern Argentina, and throughout the range of this species where they are targeted by anglers practicing C&R. Coupled with education and

engagement, best practice development based on our results may reduce potential impacts of capture and handling in emerging golden dorado recreational fisheries.

Excessive tissue damage from hooking often represents a clear negative impact in recreational fisheries (Cooke & Suski 2004; Meka 2004). Physical injury was rarely observed in our study, with hooking seldom resulting in the presence of blood or hooking in critical areas (e.g. gills). Limited hooking injury observed in our study may be due to flies being actively fished (they are moved through the water to provoke a strike) and that there is only a single hook being used (i.e., no treble hooks). Studies have shown that passive fishing can result higher rates of deep hooking (Alós 2009). This could be tested with golden dorado by comparing hooking injury when flies are actively fished to passively fished gear with single hooks and bait. In our study we also observed that anglers inadvertently removed golden dorado from the water when hook removal was difficult. Barbless hooks were not evaluated in this assessment, but could assist in reducing air exposure during hook removal (Meka 2004; Cooke & Suski 2005).

Consistent with other assessments of C&R, our study indicated that capture via hook and line induces a physiological stress response for golden dorado. Specifically, the physiological assays showed a significant increase in blood glucose and lactate 1 h after angling in comparison to the baseline blood physiology values. Lactate is primarily produced when fish respire anaerobically during angling and utilize white muscle for high intensity locomotor activity, in turn, producing lactate from the metabolism of glycogen (Milligan & Wood 1986; Wood 1991). Lactate values were elevated for golden dorado exposed to air, suggesting that air exposure had an incremental negative effect on fish (Ferguson & Tufts 1992; Cook et al. 2015). As a compounding factor, this is often

attributed to the anaerobic respiration post-release when gill lamellar efficiency is affected by air exposure and resulting adhesion and collapse (Ferguson & Tufts 1992). The production of lactate and the exchange of lactate to glycogen after exhaustive muscle use is energy intensive and can prolong recovery in fish (Wood 1991). Lastly it should be mentioned that while a degree of captivity stress was likely present in our study, it was moderately uniform across treatments allowing us to compare relative differences among air exposure groups – a common caveat of many catch-and-release studies (Cooke et al. 2013).

Golden dorado showed a secondary hyperglycemic response when exposed to angling (Barton 2002). Glucose has been used as a generalized measure of stress in activities such as C&R fishing, often related to angling time (Wedemeyer & Wydoski 2008; Cooke et al. 2013; Brownscombe et al. 2015). It is generally considered important to reduce angling times to minimize physiological stress associated with capture (Cooke & Suski 2005). However, in some species fight times are not predictors of fish stress when typical gear of the fishery is used (Brownscombe et al. 2014); this was true in our study as fight time was not identified as a key predictor of glucose levels in the model selection (Table 2.2).

Blood acidosis is a response often experienced by angled fish (Brobbe et al., 1996). Blood acidosis can be correlated with the buildup of carbon dioxide (CO₂) in the bloodstream, which can be caused by air exposure and damaged gill lamella preventing gas exchange in the water (Ferguson & Tufts 1992). This is consistent with our results that showed mean pH values were highest (i.e., low acidity) for golden dorado in the baseline group and lowest (e.g., higher acidity) for golden dorado exposed to air for 2

min following capture (Fig. 2.2). Blood acidosis can also be linked to the build up of lactic acid (Milligan & Wood 1986), which may make it difficult to single out air exposure as the only stressor responsible for this physiological response (Cooke et al. 2013).

Fish physiological processes are tightly correlated with water temperature (reviewed by Gale et al. 2013). While water temperature can often influence blood physiology response to angling stress (Portz et al. 2006; Gale et al. 2013; Brownscombe et al. 2015), it was only selected as a predictor in the blood pH (with temperature compensation) linear model selection. This is likely due to the limited range and distribution of water temperatures observed during the current study. Since there is a second fishing season for golden dorado on the Juramento River in warmer months (September – December) when water temperatures can exceed 23°C, it would be prudent for future studies to determine whether higher water temperatures exacerbate the stress response for this species.

Reflex impairment can act as a simple tool for assessing condition of fish exposed to stressors (Davis, 2010). Increasingly higher reflex impairment scores occurred for golden dorado exposed to greater angling times and air exposure could be related to higher levels of muscular exhaustion and cognitive impairment (Raby et al. 2012). As with other species (e.g., bonefish, Danylchuk et al. 2007; coho salmon, Raby et al. 2012), the loss of equilibrium was a useful and simple indicator of air exposure stress in golden dorado (Fig. 2.3) and may help reduce post-release predation risk (Danylchuk et al. 2007). No significant relationship between blood physiology metrics and reflex impairment in our study could be a product of a small sample size, or the tendency of

physiological measures to fail at predicting reflexive and behavioral impairment in fish (Davis 2010). The relationships detected between reflex impairment, air exposure, and movement response support the idea that reflex scoring could be more effective at explaining universal stress response in fish (Davis 2010).

Fallback (downstream movement) can occur as a result of cumulative physical and physiological impacts associated with capture and handling in a C&R recreational fishery (Makinen et al. 2000; Havn et al. 2015). Departures from traditional migratory patterns immediately after release has been observed for catch-and-release of Atlantic Salmon (Makinen et al. 2000; Havn et al. 2015). While C&R fisheries can result in low mortality, downstream movement may be detrimental for potadromous species such as golden dorado, which travel upstream to spawn (Hahn et al. 2011). Reflex impairment was correlated with air exposure in golden dorado (Table 2.3 and Fig. 2.3) and also correlated with fallback distance downstream post-release (Fig. 2.5). The relationship between fallback distance and reflex impairment was bolstered by its selection in the linear model development as a key predictor of release movement (Table 2.2 and Fig. 2.5). As downstream movement and reflex loss may be cumulative indicators of stress, they could act as useful visual indicators that anglers can employ to ensure a positive outcome of a C&R event for fish. Conceivably the easiest reflex for anglers to monitor is the loss of equilibrium due to its simplicity and the ease of scoring (pass/fail within 3 sec).

The higher rates of upstream movement for translocated fish (Fig. 2.6) are likely an important consideration for energy use post-release. The propensity of translocated golden dorado to make large (+300 m/day) movements upstream in the direction of the

capture site implies that site fidelity may be important to golden dorado spatial ecology. This finding of increased rates of movement and capture site return for translocated fish is some of the first fine-scale work to look at golden dorado spatial ecology, and it would be judicious to further explore the implications of site fidelity and territoriality related to post-release movement. While recovery bags could aid in recovery in golden dorado and other species (Table 2.1; Brownscombe et al. 2013), the nature of this fishery (consistent downstream floating) adds an additional confounding effect for the use of these tools for fish recovery following C&R.

C&R angling for golden dorado is an important component of the emerging economy along the Juramento River, and has the potential to act as a catalyst for stakeholder engagement focused on broader environmental issues in the watershed. Working collaboratively, guides, anglers, and researchers were able to evaluate the potential impacts of a growing C&R fishery in Argentina. Understanding the fishery specific angling events that elicit the greatest stress response, reflex impairment, behavioral alteration, or injury, can lead to the development and employment of species specific, contextually relevant best practices. Ultimately, as the first study of C&R for this species, golden dorado appear to be a relatively resilient species to C&R, however anglers and resource managers should consider minimizing handling time and air exposure. Furthermore, continued evaluation is recommended to more clearly elucidate the specific C&R impacts, whether at periods of higher water temperatures or in other recreational fisheries (e.g., conventional tackle).

Table 2.1 – Summary of physiology and reflex assessments (mean \pm SD) for golden dorado following catch-and-release. RAMP1 and RAMP2 indicates reflex score values (maximum score of 1 possible for RAMP total, and 0.2 for individual reflexes, i.e. equilibrium) taken immediately after the angling/handling period and after 1 h recovery bag period, respectively. Baseline RAMP and physiology values were assessed immediately upon landing prior to any handling.

Treatment	N	Fork length (mm)	Glucose (mg/dL)	Lactate (mg/dL)	pH	RAMP1 total	RAMP1 - equilibrium	RAMP2 total
Baseline (Control)	14	492 \pm 140	55 \pm 12	50.1 \pm 16.9	7.51 \pm 0.14	0.03 \pm 0.11	0.01 \pm 0.05	n/a
Angling - 0 min air	12	552 \pm 88	125 \pm 25	169.9 \pm 46.8	7.41 \pm 0.17	0.20 \pm 0.21	0.05 \pm 0.09	0.08 \pm 0.16
Angling - 2 min air	10	560 \pm 87	126 \pm 23	176.7 \pm 31.89	7.33 \pm 0.13	0.38 \pm 0.24	0.12 \pm 0.10	0.12 \pm 0.14

Table 2.2 – Generalized linear model outputs for fallback/upstream movement (20 min post angling), blood glucose, lactate, and pH concentrations (1 h post) angling and handling events. Predictive parameters considered in the model development and selection were: fight time, air exposure treatment, water temperature, hook removal difficulty, and RAMP score.

Model Variable	Parameter	Coefficient	S.E.	DF	t-value	p-value
Glucose	Intercept	125.45	5.05	21	24.83	<0.01
Lactate	Intercept	172.97	8.47	21	20.3	<0.01
pH	Intercept	8.13	0.35	20	23.29	<0.01
	Water temperature	-0.04	0.02	20	-2.51	0.02
	Air exposure	-0.05	0.03	20	-1.73	0.1
	Hook removal difficulty	0.07	0.03	20	2.68	0.02
Fallback/upstream distance	Intercept	-2.46	24.57	18	-0.1	0.92
	RAMP total score	-107.7	58.6	18	-1.84	0.08

Table 2.3 – Linear model outputs for RAMP values immediately and 1 h after handling and angling events. RAMP scores interval of 1-3: RAMP: low score (1) = 0, Med (2) = .2-.4, High (3) = .6+

Model Variable	Parameter	Coefficient	S.E.	DF	t-value	p-value
RAMP 1 - Total						
	Intercept	1.67	0.21	20	8.058	<0.01
	Air exposure	0.53	0.31	20	1.739	0.1
RAMP 2 - Total						
	Intercept	1.36	0.11	21	12.99	<0.01

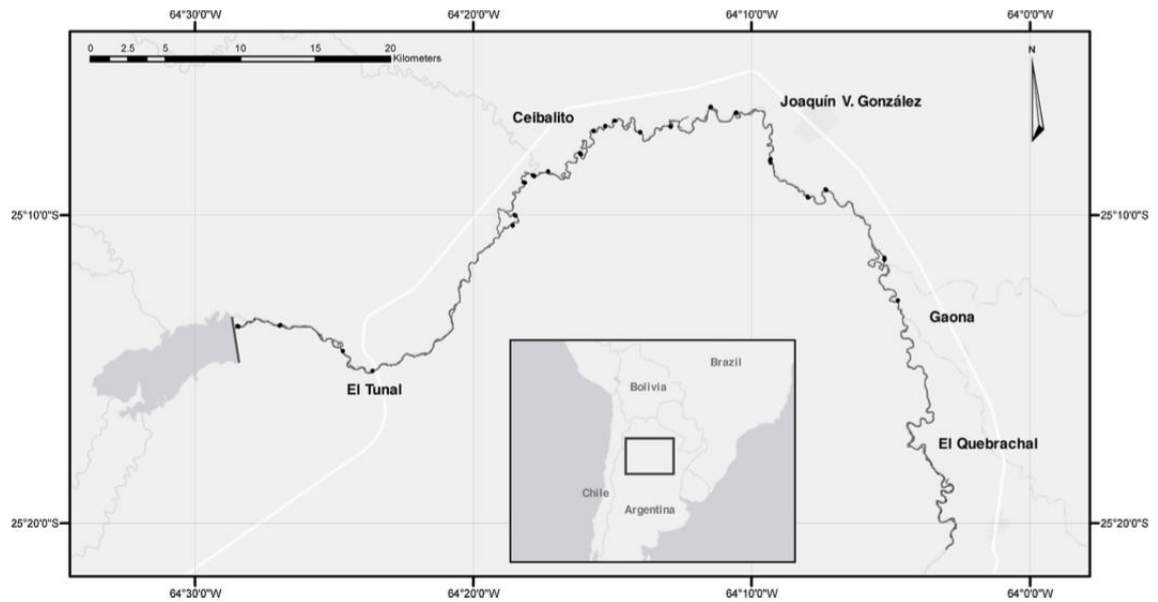


Figure 2.1 - Study area of the Juramento River in the Salta province of Northern Argentina. The river section in dark gray highlights the extent (~100 km) of the sampling area for the catch-and-release evaluation. The dark line at the reservoir west of El Tunal represents the 5 Mw hydropower dam marking the upstream delineation of the study site. Tagging locations are indicated by the black dots on the map.

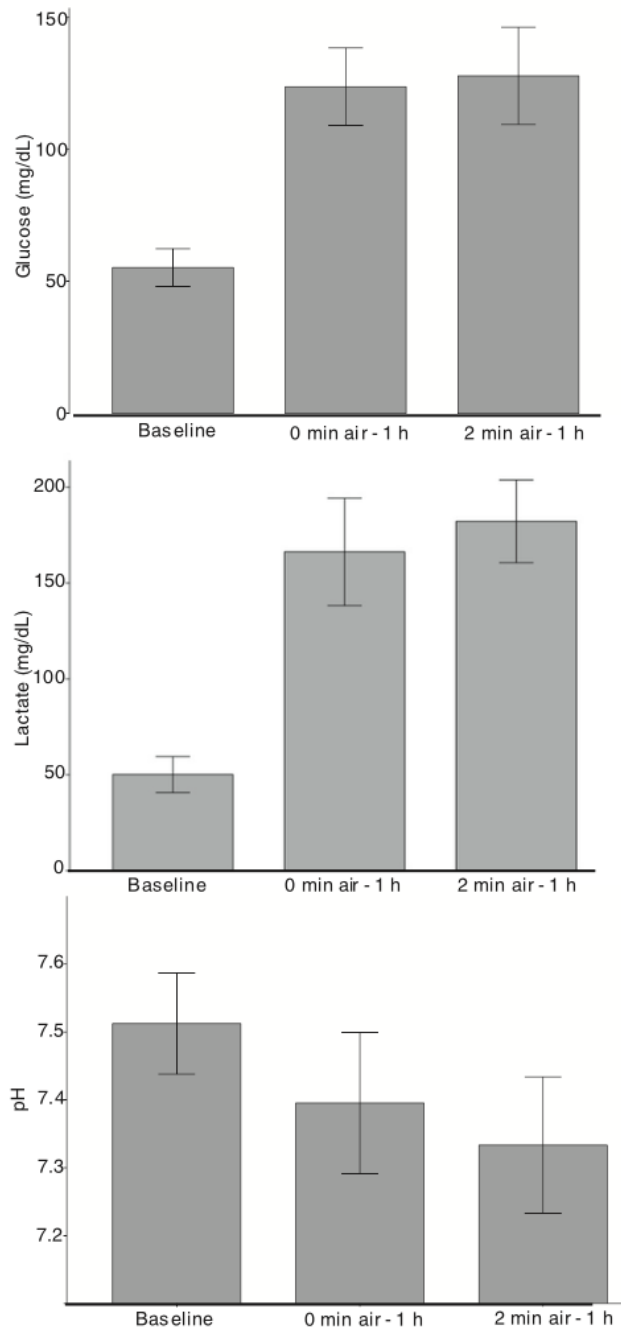


Figure 2.2 - Mean blood glucose, lactate, and pH concentrations for golden dorado. Error bars represent 95% confidence intervals around the mean. Baseline values represent blood physiology values obtained immediately upon landing and the 0 min air – 1 h and 2 min air – 1 h labels represent blood physiology values after angling and handling treatments with a one hour holding period to obtain peak physiology readings.

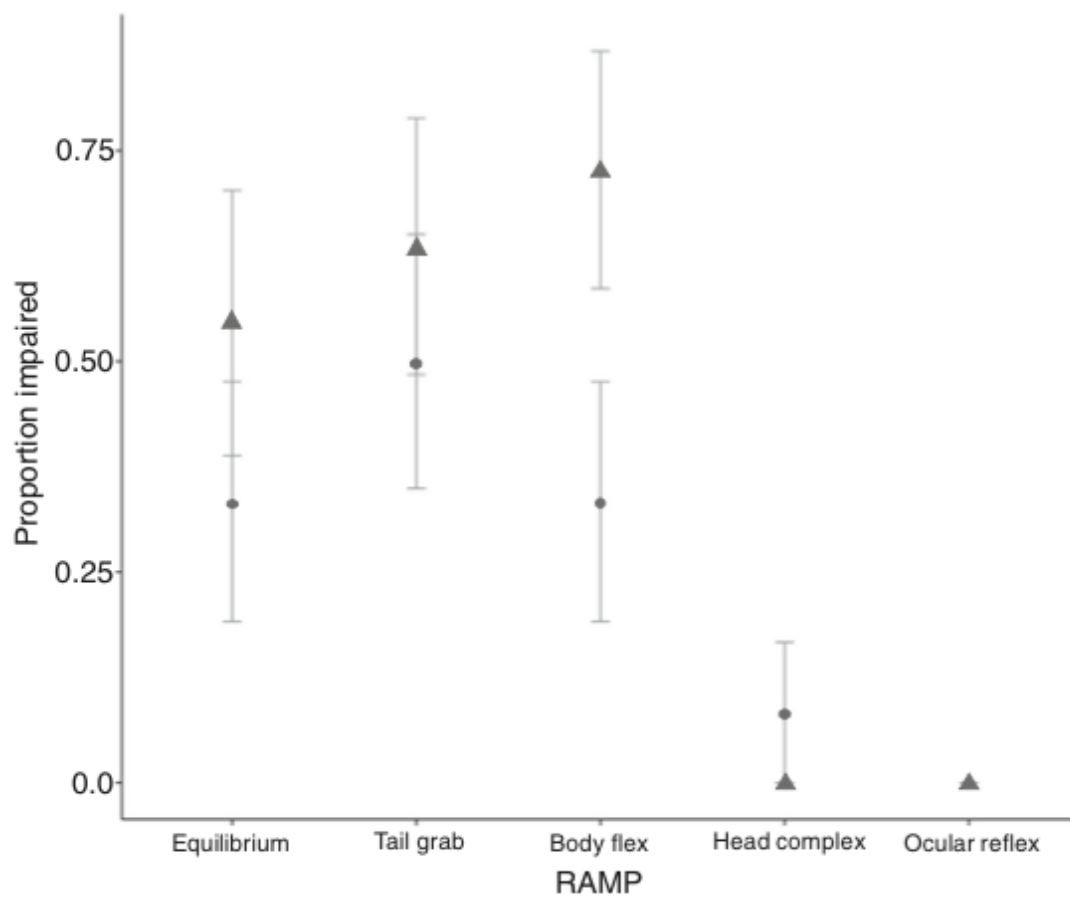


Figure 2.3 - Proportion of reflexes impaired (reflex action mortality predictors; RAMP) in golden dorado after angling, handling, and air exposure treatments (0 min exposure = circle, 2 min air exposure = triangle). Error bars shown represent standard error around the mean proportion.

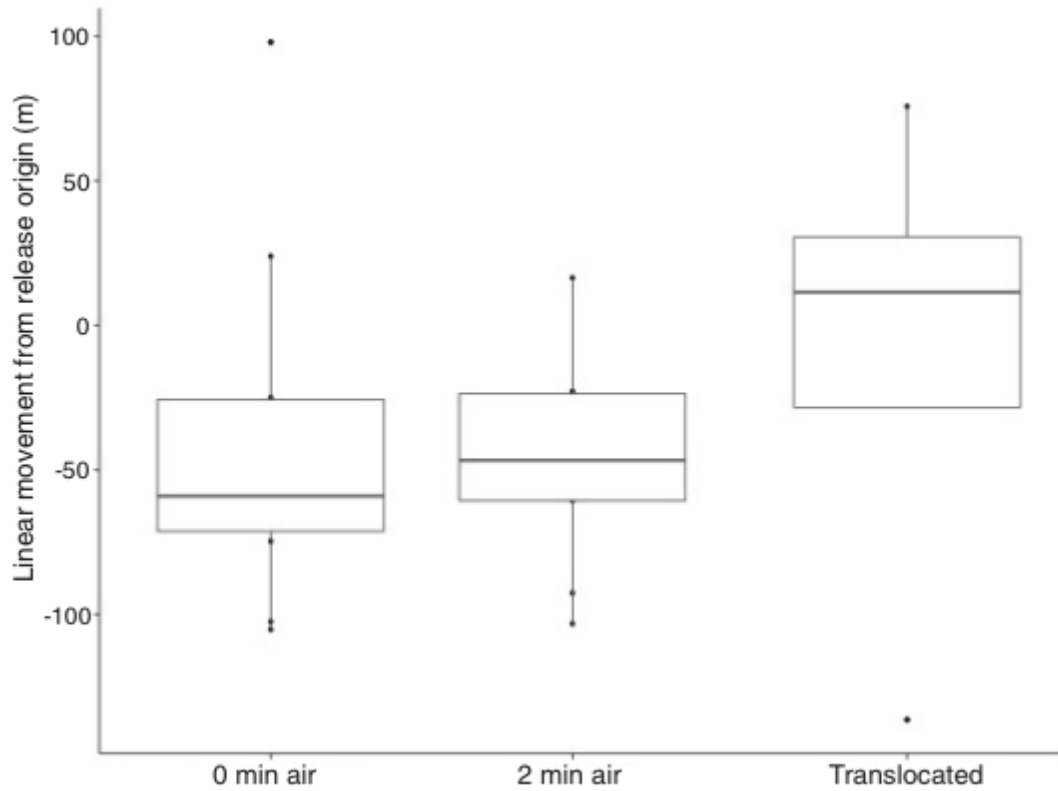
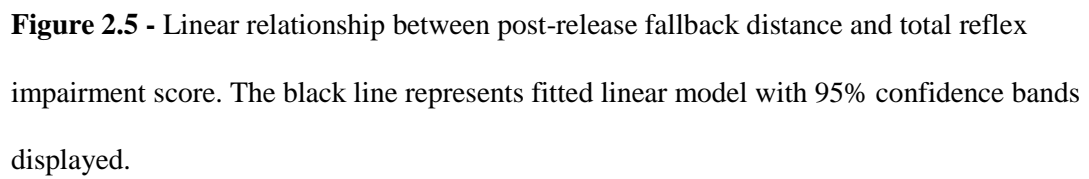


Figure 2.4 - Short-term tracking linear movement box plots between tagging treatment groups. 0 min air and 2 min air labels represent angling events where fish were immediately landed, tagged, and released with an air exposure (0 or 2 min) treatment. The translocated fish were captured drifted in recovery bags downstream ~45 min (2800 ± 909 m), tagged, released, and tracked for 20 min.



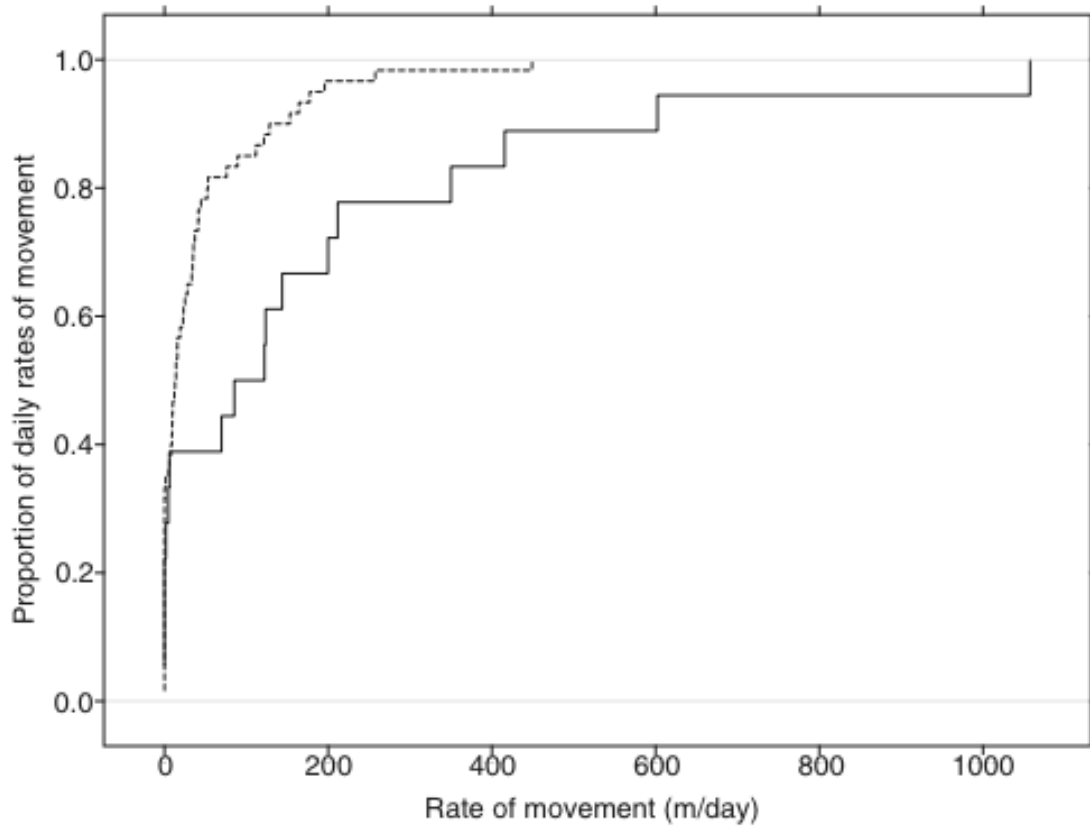


Figure 2.6 - Empirical Cumulative Distribution plot of daily rates of movement for immediate tag and release fish (dashed line) relative to translocated fish (solid line). Daily rates of movement are defined as individual river line distances between previous point of relocation divided by the time between last location.

CHAPTER 3

**MODELING INTENTIONS TO SANCTION AMONG ANGLERS IN A CATCH-
AND-RELEASE RECREATIONAL FISHERY FOR GOLDEN DORADO
(*SALMINUS BRASILIENSIS*) IN SALTA, ARGENTINA**

Abstract

Catch-and-release (C&R) is a potentially powerful tool for minimizing impact on recreationally targeted fishes. Although C&R can and often is mandated in fisheries through regulation, voluntary adoption of best practices is often critical due to minimal enforcement opportunities. In recreational fisheries where formal enforcement is lacking, anglers themselves may play an important role in increasing C&R adoption through interpersonal sanctioning, i.e., self-policing. To date, little research has examined factors that predict anglers' willingness to sanction others' behavior in C&R fisheries. We conducted in-person and online surveys with anglers who participate in a C&R fishery in northern Argentina to explore sanctioning behavior. Results show that a combination of intrinsic values, demographics, and fishing behaviors predicted anglers' intentions to sanction others. In particular, anglers with the strongest intentions to sanction were younger and more open to adopting best-practices, identified fishing as important to their lifestyle, and expressed high environmental concern relative to others anglers. Taken together, our findings highlight the important role that anglers can play in promoting C&R best practices via interpersonal sanctioning as well as some of the barriers to these types of engagement.

Introduction

Catch-and-release (C&R) angling is a growing and popular leisure activity world-wide (Arlinghaus et al. 2007; Arlinghaus & Cooke 2009; Jensen et al. 2009; Wood et al. 2013). When C&R is adopted, the assumption is that fish experience minimal post-release impacts (Cooke & Schramm 2007; Cooke et al. 2012), yet this may not always be the case (Barton 2002). A wide range of scientific studies for recreationally targeted fish species have shown that stress impacts can be minimized and best practices developed through ecological evaluation of physical and physiological condition, post-release behavior, mortality, and fitness (Cooke et al. 2013). Much less attention has focused on how anglers perceive these best practices and what motivates them to adopt and encourage others to adopt them within angling communities (Arlinghaus et al. 2013).

It is important to understand whether individuals are motivated to confront threats to resources, and what may predict these motivations in C&R fisheries (e.g., engaging in social sanctioning; Swim & Bloodhart 2013). Perceptions of threats to fisheries and local resources may be driven by a general awareness of direct environmental impact of an angling event (e.g., impacts of air exposure, water temperature, physical injury), or ingrained values and demographics (e.g., environmental concern, intrinsic values around resources, dependency on resources for economic and recreational value; Arlinghaus 2006). Research has consistently shown that environmental values, beliefs, threat saliency, and stakeholder capacity to affect change are critical for behavioral change and inform understandings of stakeholder engagement with the environment (value-belief norm theory; Stern et al. 1999; Bruskotter & Fulton 2008; Jansson et al. 2011). Moreover, pro-environmental behavior adoption research established the predictive power of values

in the early adoption of eco-innovation, such as alternative fuel vehicles (Jansson et al. 2011). It is important for C&R management to better understand what predicts individuals' motivations to alter behaviors and encourage other to do so when formal enforcement is absent (Ostrom et al. 1992). In these scenarios, best practice compliance may be best perpetuated by interpersonal confrontation.

When anglers challenge or confront destructive (lethal or sub-lethal) angling practices they are engaging in a powerful though potentially infrequent form of interpersonal communication – sanctioning (Czopp 2013). Sanctioning can serve an important function in encouraging a conservation ethic, an ethic where environmental transgressions are confronted and pro-environmental behavior encouraged (Nolan 2013; Swim 2013; Swim & Bloodhart 2013). Interpersonal sanctioning can be expressed as direct disapproval of another individual's transgression, or or may manifest in more indirect ways (e.g., non-verbal behavior demonstrations, influencing behavior through leading by example). Swim and Bloodhart (2013) found that admonishing individuals for anti-environmental behavior (e.g., elevator usage over stairs) directly boosted subsequent pro-environmental behavior rates. Although Swim and Bloodhart (2013) used a controlled experimental setting in their work, their research provides insight in to the positive efficacy of admonishment versus praise.

If sanctioning is common in a particular human-resource system, then the common opinion is that the potential costs of being sanctioned are less desirable than simple cooperation (Czopp 2013). Social costs can manifest as guilt, reputational concerns, embarrassment, and social pressure; competing costs may be perceived environmental impact and personal valuation of sanction action or consequence (Nolan

2013). In a system regulated by social sanctions, sanctioning increases cooperation by increasing the costs associated with defection. Sanctioning appears to be a relatively common descriptive norm in many C&R systems, and though injunctive norms of sanctioning may be prevalent they do not appear to be ubiquitous. In C&R fisheries where support for social sanctions is weak, the costs associated with sanctioning may be perceived as too high. Under the the current precedent, while sanctioning may be effective, confrontation may be seen as a costly violation of injunctive norms. Debatably, shifting these existing norms requires individuals that are willing to confront or sanction (Swim 2013). In this study the goal principally is to measure the degree to which there is support for social sanctions, and subsequently what motivates the existing support.

A very limited amount of research has explored the feasibility of values and demographics at predicting sanctioning intentions in the context of recreational fisheries. This paper will examine the predictors of recreational anglers' intentions and willingness to socially sanction others in a C&R fishery context. We generated survey questions *a priori* that could be evaluated for their contributions at predicting intentions to socially sanction (e.g., verbally reprimand) individuals not engaging in best practices for C&R. These surveys complimented a research project that was simultaneously conducted and investigated how the target species (Golden Dorado, *Salminus brasiliensis*) respond to C&R (Gagne et al. In Press). The framework used in this study provides an approach that could be applied to other recreational fisheries and shed light on novel paths for gauging collective stakeholder resources for sanctioning in a fishery system.

Study Site

The Juramento River is a large floodplain river and a valuable resource in the Salta province of Argentina. A diversity of stakeholders utilize the river for agricultural water supply, small scale subsistence native fish harvest, and C&R-only recreational fishing. A concern across many fisher stakeholder groups is the limited capacity of formal regulatory enforcement as fishery violations are often observed, including irrigation diversion practices and illegal fish harvest (Personal communication, recreational fishing guide, 2015). When conducted, enforcement of regulations and general watershed protection is predominantly spearheaded by community peer-groups (Personal communication, recreational fishing guide, 2015).

Two contemporary fishing sectors are prevalent in the region, a recreational fishery for golden dorado and a subsistence harvest fishery for sábalo (*Prochilodus lineatus*) and boga (*Leporinus obtusidens*) with periodic illegal harvest of golden dorado. Golden dorado in the Juramento River, Salta, Argentina, represents a fishery that has transitioned from a mixed-use fishery to a C&R-only fishery as means of promoting conservation and economic revenue (Personal communication, recreational fishing guide, 2015). For approximately two decades the majority of golden dorado fishers have been fishing with an angler-led voluntary C&R ethic, which has been further reinforced by an angler-encouraged formal regulatory mandate (Personal communication, recreational fishing guide, 2015). Recreational angling has a strong presence on the Juramento River and it has been made clear from multiple sources that enforcement capacity is limited and often nonexistent (Personal communication, recreational fishing guide, 2015).

Methods

Sample Frame and Survey Delivery

Opportunistic field sampling and Internet social media distribution was used to contact survey respondents. The sample population included anglers who were familiar with targeting golden dorado on the Juramento River. The survey delivery period coincided with one of the two primary golden dorado fishing seasons in the watershed. The survey instrument was constructed in English and translated in to Spanish by two native Spanish speakers. Both Spanish and English language surveys were made available to study participants. All surveys, including in-person were administered in the preferred language by one of our team who was proficient in Spanish and English. The social media portal was a local regional guiding operation's Facebook page with 3100 followers, which was used for regional fishing information distribution.

Survey Instrument

The survey instrument used was a 52 item semi-structured survey developed to collect quantitative (Likert scales, ranking, and multiple choice) and qualitative (open text entry) data that would inform researchers of the demographics, attitudes, fishing values, fishing practices, beliefs, and behaviors of golden dorado fishers. Interview questions were identified for relevancy and clarity by researchers and tested in the field by local fishers. The survey was hosted by QuestionPro (Seattle, WA, USA) and responses were limited to one survey per Internet protocol (IP) address based on recommendations by Bowen et al. (2008). The survey protocol was approved by the Institutional Review Board at the University of Massachusetts Amherst (Protocol ID: 2015-2517).

Variable Selection

Variable selection was conducted in a reverse hierarchical manner starting from the angling event. Component selection began with specific angling practices (Danylchuk et al. 2011), moving to general angling decisions and typology (Fisher 1997), attitudes and beliefs surrounding fishing (Granek et al. 2008; Nguyen et al. 2013), broader concerns and opinions on watershed scale topics (Bower et al. 2014), and lastly general social demographics. Through this methodical *a priori* decomposition, building blocks were selected that could be components of a full regression model. The intent of the variable selection was to merge traditional knowledge with objective selection that was open to critique and revision. This method can transfer to other recreational fishing systems asking similar questions (Arlinghaus et al. 2013).

To specifically categorize anglers, the survey asked a number of questions about angler segmentation (i.e. gear choices, C&R vs. harvest, fishing significance to lifestyle, annual fishing days) along with a number of traditional classification variables (i.e. salary, province of origin, age). Surveys also asked respondents a number of questions about current handling practices related to air exposure and willingness to affect self-change for suggested best practices. Explicitly, anglers were queried about average air exposure periods (see Gagne et al. In press) and if they would be willing to eliminate air exposure from when handling golden dorado. Anglers were then asked a variety of items measuring direct and relative levels of environmental concern, threat salience surrounding angling practices, and environmental degradation. Separately, general perceptions of knowledge and efficacy surrounding the fishery, management, and

research were investigated. Questions were also asked about perceptions of recreational fishery development, inclusion in the management process, the value of research in the decision making process, and the degree to which personal angling behaviors are perceived as threats to the fishery health was also examined (i.e. air exposure, rough handling).

Sanctioning

The core objective of the survey was to gauge anglers' propensity to sanction other anglers observed performing practices that negatively affect the survival and fitness of golden dorado. We developed a multi-item measure to reliably assess sanctioning intentions; no context-appropriate existing measure of willingness to sanction exists, as far as we know. Items related to sanctioning asked about likelihood, willingness, and perceived responsibility to sanction. Relationships among the sanctioning items were explored using a combination of correlation plots and exploratory principal components analysis, and a highly reliable ($\alpha=0.82$, $M=4.77$, $SD=1.61$) single factor measure was developed. The distribution was normal (Shapiro-Wilk test, $W=0.95$, $p=0.06$). The four items included in the measure were:

- *"It is my responsibility to confront anglers when they engage in practices harmful to the survival of dorado"* (Likert 1-7, strongly disagree to strongly agree)
- *"I would be willing to personally reprimand an angler that I see engaging in practices harmful to the survival of dorado"* (Likert 1-7, strongly disagree to strongly agree)

- *If you see someone performing practices that negatively affect the survival of dorado, how likely are you to confront that person about their actions?* (Likert 1-7, not likely to very likely)
- *How likely are you to warn an individual you observe exposing a dorado to air for an excessive period of time? (over 1 min)* (Likert 1-7, very unlikely to very likely)

Data Analysis

Questions addressing the selected predictors were quantitatively analyzed to explain predictors of sanctioning intentions. Basic angler descriptives are summarized (Table 3.1) across the sample. Quantitative data were also screened so that predictors included in the multiple linear regression models would fit multiple regression assumptions. Confirmation of measure development was investigated using exploratory principal components analysis and Pearson's r . Final measures to be included in the model development were tested for reliability using a Cronbach's Alpha cutoff of $\alpha > 0.6$.

Initially a number of pairwise correlations were run to explore relationships between the sanctioning measure and angler attitudes and behaviors. Correlations observed during exploratory analysis were used to inform and guide the multiple regression model development and model variable selection. Linear regression model tables are presented with coefficient estimates, t-values, individual p -values and lmg relative importance values (Grömping, 2009; Lindeman 1980). Lmg is a metric for assessing relative importance of variables in linear models; lmg is a decomposition of the model explained variance into a non-negative contribution value. An AICc table (Table 3.6) is also presented to provide context of the range of AIC, AICc values (Akaike

information criterion with correction for finite sample sizes), R^2 values, adjusted R^2 values, and degrees of freedom for the models presented and considered in this paper.

Results

Survey Response and Respondent Characteristics

Between May 10 and July 15, 2015, a total of 49 surveys were completed with electronic tablets in the field (27%) and through local social media outlets (73%), with a completion rate of 57.7% and a median of 20 minutes to finish the survey. Demographics and fishing characteristics of the respondents are presented in Table 3.1.

Descriptive Statistics and Sample Responses

All anglers were asked about angling and handling practices, preferences, and willingness to alter current practices. Anglers were asked to score angling events (1=not at all important, 5=extremely important) by the level of importance they anticipated a given angling event to have on post-release survival of a golden dorado. Anglers on average scored air exposure with the highest average score ($M=4.46$, $SD=0.75$), followed by fight time ($M=3.83$, $SD=1.01$), hook damage and gear type ($M=3.52$ (both), $SD=1.21$, 0.89, respectively), and water temperature ($M=3.17$, $SD=1.22$). Related to C&R, 95.9% of respondents estimated that 80%-100% of their fishing was C&R (see Table 3.1 for additional angler typology, i.e. gear type, etc.). Anglers were also asked to score (1 = Not likely, 7 = Very likely) their willingness to ensure caught fish would remain fully submerged prior to release, 24% scored a 4 or less, and 76% scored a 5 or above (57.5% scored 7 i.e. “very likely”).

When asked about concern for the environment, 77.8% of respondents expressed that they are “very concerned” (highest possible value) about environmental protection (*How concerned do you feel about protecting the local environment?*). Thus, participants in our sample rated themselves very high in environmental concern. Due to this effect, we did not focus on this item in the regression due to severe skew and ceiling effects generated by the question wording. A more normal response was found when anglers were asked to report their perceptions of how concerned they are about the environment relative to most anglers they know (*Compared to most anglers you know, how concerned are you about protecting the local environment?*, -3 = much less concerned, 0 = equally concerned, +3 = much more concerned). The distribution was less skewed for this measure with 33% at the midpoint or below (indicated less environmental concern relative to other anglers), and 67.4% at 5 or greater.

Anglers expressed wide-ranging attitudes regarding the efficacy of their role in management and their familiarity with regulation development. 81.3% of respondents felt that it was “very important” to include fishers, guides, and the community in management decision-making. 52% of anglers have greater than 5 conversations a month about fishery management, and 71.4% of anglers perceived conflict between anglers and river adjacent landowners. Anglers shared and received the highest proportion of management and regulation information through social media (45.8%), personal conversation (33.3%), industry websites (10.4%), and followed last by government web and paper material (2%).

The variation in responses revealed by the sanctioning intentions measure and individual items highlighted the diversity of sanctioning intent across the respondent

sample. The measure analyzed was a 1-7 (low to high intention to sanction) response of sanctioning intention. In addition to the focal four-item composite sanctioning intention measure, two separate questions also asked about what specific actions anglers would take in response to observing an act of environmental transgression on golden dorado. None of respondents said they would ignore the action. The highest proportion stated they would inform the authorities (38.3%), followed by asking anglers to not perform the action in the future (34%), and confronting the angler directly (17.02%). In addition, there were a number of open-ended text entry responses ($n = 4$).

Text entry responses centered around the idea of sanctioning acting as an opportunity for communication and best-practice broadcasting. Respondents explained that they would describe the detriments of poor handling to transgressors, with the intent that transgressors would change their behavior. Themes of ‘intention to justify’ why a transgression (i.e. air exposure) is negative were seen in open text entry responses, for example: “...I would explain the potential damage...” or “I would talk and explain...” The other predominant theme briefly observed centered around the common good and legacy, with language like: “we should take care, so that we can all enjoy this in to the future...” or “think of your children...” The sanctioning intention results highlighted the variation present across the sampled angler group.

Sanctioning Intention Regression Models

A number of exploratory combinations of pairwise correlations and principal components analyses were conducted to identify and investigate relationships between sanctioning variables, attitudes, beliefs, demographics, and risk perceptions (Table 3.2).

A few moderately high correlations were observed ($0.5 \leq r \leq 0.6$), though with multicollinearity tests, variance inflation factor (VIF) was within specifications ($\sqrt{\text{VIF}} < 2$) for multiple linear regression modeling. The multiple regression models presented here were selected using a combination of informal *a priori* selection (Tables 3.3-3.5) and stepwise selection (Table 3.6) methods that intended to minimize AICc (Akaike information criterion with correction for finite sample sizes), while concurrently maximizing explained variance in sanctioning intentions (Tables 3.3-3.5). The models are presented openly with effect sizes, and significance noted to highlight the explanatory value of the models, while also recognizing the limitations imposed by the sample size.

Model 1: Model 1 is the largest selection of variables considered in the regression modeling. Variable inclusion was driven by variables that had a response distribution to allow for prediction, fit regression assumptions, and showed a level of individual correlations with the sanctioning measure. Model 1 explained 55% of the variance in sanctioning intentions (Table 3.3). The likelihood of zero air exposure in an angling event was the predictor with the greatest relative importance ($lmg = 0.248, p = 0.001$), followed by level of perceived environmental concern relative to others ($lmg = 0.126, p = 0.027$). Also age ($lmg = 0.038, p = 0.043$) and fishing significance ($lmg = 0.078, p = 0.014$) had small relative importance, they are both noted as significant predictors of sanctioning intentions.

Model 2: A subset of variables were selected from model 1, selection was driven by *a priori* knowledge of variables that likely had strong predictive value for sanctioning intentions, relatively large *lmg* relative variable importance, and p-values approaching

significance. Model 2 explained 59% of variance (adjusted R^2) in sanctioning intentions (Table 3.4).

Model 3: Model 3 (Table 3.5) emerged most strongly in predicting sanctioning intentions, it included engaging in best-practices oneself, perceiving greater environmental concern relative to other anglers, younger anglers, and identifying strongly with fishing as significant to one's lifestyle. Model 3 explained 61% of adjusted variance in sanctioning intentions. The likelihood of zero air exposure in an angling event (*a measure of an angler's willingness to change their own handling practices to ensure zero air exposure*) was the predictor with the greatest relative importance ($lmg = 0.261$, $p = <0.001$), followed by level of perceived environmental concern relative to others ($lmg = 0.169$, $p = <0.001$). Other predictive variables included in the model were age ($lmg = 0.064$, $p = 0.003$) and fishing significance ($lmg = 0.155$, $p = <0.001$).

Discussion

The golden dorado C&R fishery on the Juramento River is expected to benefit by fostering sanctioning behavior in response to damaging angling practices. Our study effectively identified characteristics of anglers most likely to engage in sanctioning action in this fishery. We examined the role that attitudes, beliefs, angling practices, and demographics play in shaping anglers' intentions to sanction observed C&R transgressions on the Juramento River. The results indicate that younger anglers, those open to adopting best practices, individuals identifying fishing as important to their lifestyle, and those expressing high relative environmental concern were most likely to report high sanctioning intentions. While past work has explored the role that sanctioning

plays in promoting conservation behavior (Czopp 2013; Nolan 2013), few studies have looked at what factors gauge intentions to sanction. Ours is one of the first studies to explore sanctioning intentions in a recreational fishery context. The findings of our research emphasize the variation that guides behavioral intentions of anglers as they define responsibilities in promoting the success of conservation initiatives such as C&R.

The multiple regression models revealed the willingness to self-alter angling practices was the single strongest predictor of sanctioning intentions. The identification of this

‘motivated behavioral flexibility’ in angling practices as a predictor may be a figurative barometer of angler support for conservation action that is present in a recreational fishery system. Identifying anglers already willing to engage in adoption of best-practice behavior could provide an estimate of human capital predisposed to engage in pro-environmental behavior (Nolan 2013). The significance of fishing to someone’s lifestyle proved to be the next important predictor of sanctioning intentions. This implies that anglers who intensely self-identify as a dorado anglers see the costs of sanctioning as worth the pro-environmental return. At nearly the same level of importance was the environmental concern predictor. Conceptually, this comparative measure may be an accurate predictor of conservation-related intentions and behaviors. The perception that one is more concerned than their peers may increase a sense of duty/responsibility to take personal action (Czopp, 2013). Additionally, since age was also a strong predictor selected in the final model, it suggests that encouragement of sanctioning and behavioral change needs be pursued through avenues that are considerate of age.

Hunt et al. (2013) highlighted that the goal of human dimension research in recreational fisheries is to understand human thoughts, actions, and feedbacks regarding fish, fishing, and governance. The key feedbacks in this context were ecological impacts of C&R and the behavioral change needed to reduce impact. On the Juramento River, in the face of limited enforcement of guidelines, our findings suggest that an alternative framework that encourages interpersonal confrontation and sanctioning may have positive impacts. The results of systematic scientific studies focused on golden dorado C&R stress response (Gagne et al. In Press) can not stand alone in influencing the management of the recreational fishery, but instead needs to work in concert with an understanding of how the angler community can influence adoption of best practices. The results emphasized that sanctioning roles in this system are likely defined by a narrow subset of anglers. Moving forward in a sanctioning specific context, it will be important to closely outline the varied cost-benefit rationalizations that anglers go through as they demonstrate their intention to sanction with direct action. The identification of this narrow but potentially influential actor group highlights that conservation outcomes can benefit by focusing efforts on studying humans and fish as not isolated but interacting entities (Liu et al., 2007; Schlüter et al., 2012). Future work will benefit other fisheries by cross-validating our model with survey development and deployment in alternative recreational fisheries, as well as looking at the relationship between sanctioning intentions and actual sanctioning action.

Conclusion

Interpersonal sanctioning shows promise of overcoming conditions of restricted conventional management (Ostrom et al. 1992), and in this research its specific potential was shown on the Juramento River. In this and other recreational fisheries, interpersonal communication is consistently a powerful component that shapes experience, values, and behavior of anglers (Fenichel et al. 2013). On the Juramento River, younger anglers, who are receptive to conservation best practices should be recognized as playing influential and critical roles in conservation. Work presented in this paper is a novel exploration for recreational fishery science, both in its predictive nature and in the intention to outline the interplay between strong and weak sanctioning angler characterizations. In summary, this research emphasized the role that interpersonal sanctioning may play in perpetuating conservation through the adoption of C&R best practices.

Table 3.1: Social-demographic and angling summary of anglers from the dorado angler sample

Socio-demographics and other covariates	Count	%	Socio-demographics and other covariates	Count	%	Socio-demographics and other covariates	Count	%
<i>Do you practice catch-and-release and/or catch-and-keep? (n=48)</i>			<i>Age (n=47)</i>			<i>Are you a member of a fishing club (n=42)</i>		
Catch-and-release	41	85.4	<20 yrs	2	4.3	No	32	76.2
Catch-and-keep	0	0.0	20-29 yrs	4	8.5	Yes	10	23.8
Both	7	14.6	30 - 39 yrs	17	36.1	<i>Province of origin (n=42)</i>		
<i>Gender (n=47)</i>			40 - 49 yrs	16	34	Salta	18	42.9
Female	1	2.2	50 - 59 yrs	4	8.5	Jujuy	4	9.5
Male	46	97.8	60 - 69 yrs	4	8.5	Cordoba	5	11.9
<i>How many conversations a month about management and regulation? (n=48)</i>			>70 yrs	0	0	Buenos Aires	5	11.9
0 times	5	10.4	<i>Avidity: how many days did you fish in the last 12 months (n=49)</i>			Other	9	21.4
0 - 2 times	11	22.9	<10 days	7	14.3	<i>Gear (n=35)</i>		
3 - 5 times	7	14.6	10 - 29 days	10	20.4	Fly	22	62.9
5 + times	25	52.1	30 - 50 days	18	36.7	Spin	1	2.9
<i>Average air exposure (n=47)</i>			>50 days	14	28.6	Fly and Spin	8	22.9
0 min	3	6.4	<i>What other species do you target? (n=38)</i>			Other	4	11.4
0 - 1:00 min	23	48.9	Trout/Salmon	10	26.3	<i>What countries have you fished in? (n=44)</i>		
1:01 - 2:00 min	14	29.8	Surubi (Catfish)	5	13.2	Bolivia	18	40.9
2:01 - 3:00 min	6	12.8	Boga	5	13.2	Cuba	7	15.9
3:01+ min	1	2.1	Marine species	7	18.4	Mexico	8	18.2
<i>Income USD (n=28)</i>			<i>Where do share management information and knowledge? (n=47)</i>			Brazil	11	25.0
0 - 10,000	9	32.1	Industry websites	5	10.6	<i>Where do you receive recreational fishing information generally? (n=47)</i>		
10,000 - 25,000	8	28.6	Personal blogs	3	6.4	Industry websites	11	23.4
25,000 - 50,000	4	14.3	Social media	22	46.8	Personal blogs	3	6.4
50,000 - 75,000	4	14.3	Pers. conversation	16	34.0	Social media	19	40.4
75,000 - 100,000	2	7.1	Govt. paper material	1	2.1	Pers. conversation	9	19.1
>100,000	1	3.6	Govt. web material	0	0.0	Govt. paper material	0	0.0
						Govt. web material	1	2.1

Table 3.2: Pearson's r correlation coefficients (*bottom left*) and corresponding p -values (*italicized, top right*) for angler survey metrics.

	Fishing Days Per Year	Fishing Days Per Year	Age	Management Familiarity	Fishing Significance	Tension Concern	Harvest Threat	Likelihood of Zero Air Exposure	Community Impact	Environmental Concern	Sanctioning Intention	
Fishing Days Per Year	0.08	0.08	0.08	0.66	0.10	0.00	0.28	0.42	0.07	0.23	0.20	0.08
Years Fishing	0.28	0.00	0.73	0.29	0.12	0.35	0.09	1.00	0.61	0.78	0.89	
Age	0.25	0.48	0.22	0.76	0.30	0.59	0.16	0.99	0.24	0.65	0.20	
Management Familiarity	0.15	0.01	0.26		0.04	0.08	0.01	0.19	0.40	0.21	0.11	0.05
Dorado Importance	0.31	-0.08	0.10	0.46		0.01	0.23	0.24	0.00	0.00	0.74	0.04
Fishing Significance	0.62	0.30	0.24	0.27	0.54		0.17	0.21	0.22	0.00	0.80	0.00
Tension Concern	0.27	0.07	0.09	0.33	0.42	0.26		0.71	0.04	0.09	0.63	0.01
Harvest Threat	0.11	-0.29	-0.27	-0.18	0.26	0.21	0.08		0.03	0.11	0.32	0.13
Likelihood of Zero Air Exposure	0.29	0.03	0.02	0.09	0.43	0.23	0.42	0.35		0.07	0.06	0.00
Community Impact	0.23	-0.01	-0.08	0.15	0.49	0.47	0.19	0.33	0.28		0.61	0.03
Environmental Concern	0.20	0.09	0.16	0.26	-0.10	-0.06	0.18	-0.15	0.27	-0.09		0.00
Sanctioning Intention	0.29	0.02	-0.11	0.27	0.29	0.38	0.38	0.27	0.65	0.28	0.43	

Table 3.3: Multiple regression table for model 1 predicting sanctioning behavior and intentions by Juramento River dorado catch-and-release anglers.

Predictors	Coef. Estimate	t-value	p-value	<i>lmg</i>
(Intercept)	-0.311	-0.145	0.885	
Fishing Days Per Year	-0.185	-0.87	0.391	0.022
Years Fishing	0.01	0.071	0.944	0.004
Age	-0.37	-2.108	0.043	0.038
Management Familiarity	0.168	1.471	0.151	0.037
Dorado Importance	-0.436	-1.289	0.207	0.026
Fishing Significance	0.496	2.614	0.014	0.078
Tension Concern	0.055	0.505	0.617	0.043
Harvest Threat	0.072	0.422	0.676	0.028
Likelihood of Zero Air Exposure	0.508	3.828	0.001	0.248
Community Impact	0.012	0.081	0.936	0.02
Environmental Concern	0.373	2.327	0.027	0.126
<i>Model Summary: R² (Adjusted R²)</i>		0.55		

Table 3.4: Multiple regression table for model 2 predicting sanctioning behavior and intentions by Juramento River dorado catch-and-release anglers.

Predictors	Coef. Estimate	t-value	p-value	<i>lmg</i>
Intercept	-1.88	-1.23	0.220	
Years Fishing	0.03	0.27	0.800	0.005
Age	-0.45	-2.79	0.008	0.060
Management Familiarity	0.10	1.07	0.290	0.042
Fishing Significance	0.39	2.74	0.009	0.111
Harvest Threat	0.06	0.35	0.729	0.024
Likelihood of Zero Air Exposure	0.41	3.74	0.001	0.224
C&R Community Impact	-0.02	-0.16	0.870	0.033
Environmental Concern	0.46	3.44	0.002	0.161
<i>Model Summary: R² (Adjusted R²)</i>		0.59		

Table 3.5: Multiple regression table for model 3 predicting sanctioning behavior and intentions by Juramento River dorado catch-and-release anglers.

Predictors	Coef. Estimate	t-value	p-value	<i>lmg</i>
(Intercept)	-1.581	-1.541	0.131	
Age	-0.413	-3.176	0.003	0.064
Fishing Significance	0.431	3.906	<0.001	0.155
Likelihood of Zero Air Exposure	0.422	4.397	<0.001	0.261
Environmental Concern	0.496	3.976	<0.001	0.169
<i>Model Summary: R² (Adjusted R²)</i>		0.61		

Table 3.6: AIC model table, top 4 models are models selected from AICc all-subsets automated selection.

Rank	Model	K	AICc	$\Delta AICc$	Adj. R^2
1	age+fishing_signi+tension_conce+submerge_likeli+enviro_conc2	5	133.478	0	0.58
2	age+fishing_signi+mgmnt_famil+tension_conce+submerge_likeli+enviro_conc2	6	134.82	1.342	0.58
3	age+days_yearly+fishing_signi+tension_conce+submerge_likeli+enviro_conc2	6	134.923	1.445	0.58
4	age+fishing_signi+dorado_importance+mgmnt_famil+tension_conce+submerge_likeli+enviro_conc2	7	135.686	1.992	0.59
Full	days_yearly + years_fishing + age + mgmnt_famil + dorado_importance + fishing_signi + tension_conce + harv_threat + submerge_likeli + community_impact + enviro_conc2	11	151.08		0.55
Dan	years_fishing + age + mgmnt_famil + fishing_signi + harv_threat + submerge_likeli + community_impact + enviro_conc2	8	147.63		0.58
p-value	age+fishing_signi+submerge_likeli+enviro_conc2	4	136.78		0.61

CHAPTER 4

SUMMARY AND FUTURE RESEARCH

Integrated Summary

C&R (catch-and-release) fisheries are growing in transitioning economies, underdeveloped regions, and emerging countries (Granek et al. 2008; Bower et al. 2014; Cooke et al. 2014). Central to these new fisheries are novel fish species with distinct environmental conditions, life history, and potential response to C&R angling (Cooke et al. 2014). Many of these regions also face unique social complexities, such as constrained management and enforcement resources, social-economic conflict, and resource competition (Arlinghuas et al. 2007; Hunt et al. 2013). Golden dorado in South America is a species growing in popularity as a target of recreational anglers practicing C&R. However, until my thesis research, there were no studies on how golden dorado respond to C&R, the social context of the angling community, or the the adoption of best practices.

When examining how golden dorado respond to a C&R angling event, my results showed that angled and handled golden dorado had significantly higher blood glucose and lactate concentrations relative to the baseline levels. Additionally, golden dorado with air exposure after being landed showed higher cumulative reflex impairment scores, especially the loss of equilibrium. Furthermore, fallback of radio tagged golden dorado was greater for individuals with higher reflex impairment scores. No immediate mortality was observed following release, though short-term mortality could have been as high at 8%. My mortality estimate was a function of the 2 fish of 24 tagged not being relocated for the entire tracking period. My estimate is presented as a maximum mortality because

tag loss or tag malfunction may have contributed to overestimation. Post-release movement for translocated fish also suggested that site fidelity could be an important component of golden dorado spatial ecology. Site fidelity appeared relevant because fish that were tagged and translocated downstream showed higher rates of movement in the direction of the capture site. Collectively, these results strongly suggest that eliminating air exposure and releasing fish close to capture site can minimize impacts related to C&R. In addition, the loss of equilibrium is a tool that anglers can easily employ to monitor golden dorado condition prior to release.

Before my study, golden dorado were not at all evaluated for C&R stress response and, in the field of C&R science, there was no work done on their order and genus. My results highlight the unique, but also consistent stress response of golden dorado in comparison to other species. C&R stress response is a spectrum of variable effects, a spectrum where there is overlap and divide across species (Casselman 2005). Although golden dorado may exhibit unique site fidelity and strong equilibrium loss, they also exhibit relatively consistent blood physiology and fallback in line with other popular C&R species (Cooke & Suski 2005). When conducting species and regionally specific evaluations, C&R research sometimes faces criticism of looking for unnecessary variation in C&R stress impacts (Cooke & Suski 2005). Opposition often argues that C&R may be employed effectively under assumptions and guidelines implemented universally across species (Pelletier et al. 2007). My findings reinforce the notion that context is critical and justifies species-specific assessment of potential C&R stress impacts.

The effectiveness of guidelines for C&R best practices relies on their adoption by recreational anglers. Recommendations for best practices have very little conservation impact without broad angler acceptance. In other conservation arenas (e.g. recycling, electricity usage) interpersonal sanctioning has shown promise at overcoming conditions of restricted formal enforcement. My research considers ways to improve interpersonal sanctioning, aiding best practices adoption. Conceptually, sanctioning is most prevalent in systems where the costs (social or environmental) of not sanctioning are higher than the costs of engaging in confrontation (Ostrom et al. 1992; Swim & Bloodhart 2013). In my research, interpersonal sanctioning intentions were predicted and modeled by surveying a number of potential influential intrinsic and extrinsic variables such as demographics, beliefs, practices, and values. Results of the survey showed individuals with the strongest sanctioning intentions were younger anglers who were open to adopting best practices, especially those who also identified fishing as important to their lifestyle, and expressed high environmental concern relative to others. Anglers with these characteristics were most likely to perceive the cost of sanctioning (reputation, social pressure) as less than the cost of not sanctioning (environmental impact) (Ostrom et al. 1992). My research findings suggested that this cost-benefit behavioral reasoning appears to be predictable by surveying values, identity, and demographics (Nolan 2013). Additional results showed C&R anglers were most likely to receive, share, and comment on angling practices and management on social media, suggesting that management agencies could leverage limited outreach resources by engaging anglers through social media. In this recreational fishery system, I summarized the defining factors outlining the variation between strong versus weak sanctioning-minded anglers. The findings of this

research highlighted the role that anglers can have in the success or failure of conservation initiatives such as C&R. It also underlined the significance of managing recreational fisheries as social-ecological systems.

Future research direction

My study gathered evidence for best practices for C&R, and acknowledged the roles that anglers may play in enforcing evidence based best practices under constrained management. Overall, this study generated the first insights into the golden dorado C&R fishery and its findings are important to understanding the growth of C&R fisheries in remote and emerging regions. Although my research provides a great deal of insight that can guide the management of golden dorado in Argentina, additional work needs to investigate the social-economic impacts of a popular C&R golden dorado fishery and the limited knowledge of golden dorado life history and ecology as it relates to C&R impacts on fitness. Overall, growing C&R fisheries in emerging countries face numerous potential social and ecological risks with novel species and unsupervised growth (Granek et al. 2008; Arlinghaus & Cooke 2009).

As an extension from chapter two, studies focusing on the longer-term movement of golden dorado could provide important insights into home range, spawning movement patterns, habitat use, and implications of territoriality. More detailed tracking and analysis of long-term golden dorado movement can provide important information about when golden dorado may be most vulnerable to high-impact stress events, including: angling during migratory periods (Richard et al. 2013), angling in high pressure spatial zones (e.g. dam tailwaters, Agostinho et al. 2008), and removing fish temporarily from

home ranges (Cooke et al. 2000). Additionally, anglers and guides in the region consistently reported post-release predation. Since this work did not evaluate post-release predation risk, further work should evaluate the level that this risk may contribute to the C&R mortality estimates (Danylchuk et al. 2007). This thesis has strengthened the notion that C&R impact research needs to be recognized as an iterative process, one that is continually adapting to new findings.

Overall, golden dorado spatial ecology and movement is poorly understood; longer term studies incorporating telemetry can provide detailed movement data that is beyond the scope of this research (Jepsen et al. 2002; Hahn et al. 2011). For example, no research has specifically outlined the spawning impacts of impoundments along rivers that golden dorado inhabit. With the assumption that golden dorado make long potadromous movements during spawning, impoundments may be having significant impacts on population dynamics. Additionally, little work has looked at the importance of flooded habitat for spawning and juvenile growth. With extremely limited data, any additional ecological information may lead to insights that influence management and conservation practices in neotropical river watersheds for this top trophic level predatory fish.

Chapter three explored the motivators behind the sanctioning intentions of golden dorado anglers in Salta, Argentina. Though, despite the useful findings, additional research is needed to examine how the adoption of conservation practices are perpetuated and adopted by anglers (Danylchuk et al. 2011). Findings from chapter three reinforced that behavioral intentions are regulated by values, beliefs, practices, and demographics to varying degrees. With this understanding, future work with all growing C&R fisheries

would benefit by cross-validating the employed methodology of assessing angler capital for sanctioning. In addition, I would suggest exploring how strongly behavioral intentions translate to direct action, specifically if sanctioning intentions lead to sanctioning action. If the method of surveying anglers' values, identity, beliefs, practices, and demographics proves to be predictive of behavioral change in other C&R fisheries, then it could be a powerful tool to understanding behavioral change for conservation. As C&R fisheries emerge in diverse locales with varied social and economic conditions, we should continue to build and utilize interdisciplinary tools that treat C&R fisheries as complex and coupled social-ecological systems.

Conclusion

In my thesis I consider both the ecological and social implications of growth of a golden dorado C&R fishery in Salta, Argentina, while providing guidance for management of golden dorado in a context specific manner. As a collective unit, my thesis offers a transferrable framework of assessment for other golden dorado and remote C&R fisheries. Ideally this framework recognizes the coupled human and nature elements of sustainable C&R management. In a preferable application, the info collected here will be used in the development of a conservation and management plan for golden dorado in Salta. Findings of this thesis satisfy an interdisciplinary void in C&R research, and fills needs in the fields of both recreational fishery science and environmental social science. As researchers, it will be prudent to continue recognizing each recreational fishery as entirely unique, having conservation needs and barriers that are highly varied. Our lens for study design will need to remain open to adaptation and refinement.

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